LIST OF PUBLICATIONS OF THE OFFICE OF EXPERIMENT STATIONS ON IRRIGATION.[a]

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Bul. 104. Report of Irrigation Investigations for 1900. Under the supervision of Elwood Mead, expert in charge of Irrigation Investigations. Pp. 334. Price, 50 cents.

Bul. 105. Irrigation in the United States. Testimony of Elwood Mead, irrigation expert in charge, before the United States Industrial Commission June 11 and 12, 1901. Pp. 47. Price, 15 cents.

FARMERS' BULLETINS.

Bul. 46. Irrigation in Humid Climates. By F. H. King. Pp. 27.

Bul. 116. Irrigation in Fruit Growing. By E. J. Wickson. Pp. 48.

Bul. 138. Irrigation in Field and Garden. By E. J. Wickson. Pp. 40.

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[a] For those publications to which a price is affixed application should be made to the Superintendent of Documents, Union Building, Washington, D. C., the officer designated by law to sell Government publications.

U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN NO. 108.

A. C. TRUE, Director.

IRRIGATION PRACTICE

AMONG

FRUIT GROWERS ON THE PACIFIC COAST.

BY

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OFFICE OF EXPERIMENT STATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., November 15, 1901.

Sir: I have the honor to transmit herewith a report on Irrigation practice among fruit growers on the Pacific coast, by E. J. Wickson, M. A., and to recommend its publication as a bulletin of this Office. This report has been prepared under the direction of Prof. Elwood Mead, expert in charge of the irrigation investigations of this Office. It presents the results of a special investigation into the conditions, extent, and methods of irrigation as practiced among fruit growers on the Pacific coast. The data on which it is based were gathered during a period extending over several years and involved the cooperation of many fruit growers in the States of Idaho, Washington, Oregon, California, and Nevada, and the Territory of Arizona. It is believed that the information contained in the report will suggest further thought and inquiry on the part of those interested in fruit growing throughout the West.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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IRRIGATION PRACTICE AMONG FRUIT GROWERS ON THE PACIFIC COAST.

INTRODUCTION.

In an earlier publication[a] by the Department of Agriculture the writer attempted to state briefly the principles of irrigation applied to fruit growing as deducible from the experience of Pacific coast growers and to describe and outline the irrigation practices which have given best results. The data for that work were drawn, not alone from the writer's general knowledge of the subject, but from wide special investigation authorized by this Department. In 1898 very careful inquiry was made, by correspondence and travel, into the local irrigation practices on the Pacific coast, in connection with a study of the distribution of fruit varieties under the direction of G. B. Brackett, Pomologist of this Department. This involved the cooperation of nearly five hundred growers in the States of Idaho, Washington, Oregon, California, Nevada, and the Territory of Arizona. In 1899 and 1900 the data already secured were reviewed and verified, and much additional information secured by supplementary inquiry. The writer has been actuated by a desire to secure as full and accurate exposition of irrigation practice in fruit growing as could be secured by the means at command. The point of view of the grower has been steadily held, but, of course, due effort has been made to avoid errors arising from the personal equations of the individuals contributing to the results. Whenever possible the inquiry has been pushed to the last attainable point, so that vague and misleading generalizations might be avoided. The subject is itself intricate and the deductions in many cases fall short of being conclusive, yet the effort to concentrate and interpret the experiences of hundreds of practical men who are pledging their livelihoods to the accuracy of their conclusions should yield a valuable contribution to the understanding of irrigation problems and supplement the data secured by irrigation engineers, who approach it from other points of view and by other methods.

As the inquiry has been restricted to the actual practice of irrigation by the fruit grower, the writer denies himself discussion of the general physical features of the areas covered. These are set forth

[a] U. S. Dept. Agr., Farmers' Bul. 116.

quite fully in various reports, and only enough data will be offered to locate the regions under consideration and briefly characterize conditions which are most obviously related to irrigation practice. No attention will be given to water supply, nor to other matters usually relegated to the sphere of engineering. Data and discussion will be restricted to the distribution and use of water after it has reached the land of the irrigator. By adhering to this division of the subject it is hoped to give this report a special character and value.

REGION INCLUDED IN THE INVESTIGATION.

The area included in this inquiry is indicated upon the accompanying map (Pl. I) and comprises, wholly or in part, the States of Idaho, Washington, Oregon, California, Nevada, and the Territory of Arizona. The boundaries of the region included are somewhat arbitrary and are largely prescribed by the limits of the writer's sources of original information, and the included area is not claimed to be in all respects similar throughout nor distinct from adjoining regions. Yet this particular strip of country adjacent to the Pacific Ocean has a characteristic difference from any other section of the United States extending through so many degrees of latitude, in that certain of the more tender fruits of the temperate zone, including certain varieties of grapes of the *vinifera* species, flourish at both its north and south extremes. This fact argues a similarity of natural conditions within the limits of the needs of these fruits, and, although facts are abundant to show that the diversity of natural conditions within narrow areas is exceedingly great, there are certain other natural conditions which are widely common.

The map is intended to give a general view of the distribution of irrigation practice. It is not claimed, of course, that all the land included in each color division is suited for fruit growing nor that irrigation facilities have been developed to the extent indicated. It is, however, approximately true that wherever suitable fruit soils exist and the land is topographically adapted to fruit growing the practice must as a rule conform to that prescribed for the region. It is true also that here and there, so far as settlement and development have proceeded, fruit is actually being grown on a commercial scale with or without irrigation, as indicated, in the different regions on the map. The breadth of the data on which the map rests is suggested by the tabulations which will follow. These data, supplemented by the writer's personal acquaintance with the facts, justify the separation of the included territory into three divisions, as follows:

THE NONIRRIGATED AREA.

This comprises the immediate coast slopes, so far as the local climate favors fruits; also the coast valleys, which are measurably protected


MAP
OF
PACIFIC COAST REGION
SHOWING
DISTRIBUTION OF IRRIGATION
IN GROWING DECIDUOUS FRUITS.
LEGEND
No irrigation
Partial or occasional irrigation
Regular irrigation
PACIFIC OCEAN
WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
UTAH
ARIZONA
Olympia
Salem
Boise
Sacramento
Carson
Salt Lake City
Prescott
COLUMBIA RIV.
CASCADE RANGE
BLUE MTS.
COAST RANGES
SIERRA NEVADA
Snake River
Great Salt Lake
Tulare Lake
San Joaquin Riv.
Sacramento
COLORADO RIVER
Rio Gila Riv.
JULIUS BIEN & CO. N.Y.

from coast winds by hill or mountain ranges and separated from the interior valleys by higher mountain ranges. This region is broadest at the north, where it covers an elevated region extending from the coast to the eastern limits of the area covered by the present inquiry, including the northern panhandle of Idaho. It extends southward on the coast side, including western Washington and Oregon, widens with the eastern trend of the mountains so as to include a portion of the higher lands in northern California, and then proceeds southward along the coast, narrowing as the Coast Range nears the coast in northwestern California until it reaches the Bay of San Francisco. South of this point the strictly nonirrigated region is of comparatively small area and of small account, relatively, in commercial fruit growing. In western Washington and Oregon, and for a certain distance along the coast in northern California, the region has humid characteristics in its heavy rainfall and long, rainy season, yet it has a two-season year, and in some localities the smaller rainfall and the stress of the dry season bring the fruit growers near to the conclusion that irrigation would sometimes be desirable and profitable. The same conditions exist in the small elevated areas indicated as nonirrigated in southern California.

THE PARTIALLY OR OCCASIONALLY IRRIGATED AREA.

This extended area, as shown on the map, is based upon the new conception of the local needs of irrigation and the very free recourse to it, resulting from several recent years of deficient rainfall, which produced a destructive drought in some parts of California. This drought, coupled with the demonstrated fact that the needs of mature trees bearing large crops are much greater than the needs of younger trees, has resulted in a changed view as to the necessity and profitableness of irrigation and has sharply modified practice. The area in which irrigation is now recognized as an important factor, either as a regular supplement to normal rainfall or as an occasional expedient to insure thrift of trees and satisfactory size and quality of fruit when rainfall is less than normal, is vastly greater than formerly thought possible. Investment in irrigation works, undertaken from this new point of view, has proved very profitable. Naturally, this area includes the old district where partial irrigation has always been pursued, and is, in fact, a vast extension of this district. The term "partial irrigation" is, then, adopted to signify that the main growth of tree and fruit is accomplished by rainfall. The term "occasional irrigation" indicates the use of irrigation when the rainfall falls below normal.

The area which it is now deemed good policy to irrigate is seen by the map to extend throughout almost the whole north and south extension of the region mapped, and in the main to lie between the nonirrigated and the regularly irrigated regions, although it departs from this by following the higher foothills of the Sierra Nevadas.

The lower foothills of the same range, both on the east and west flanks, and the valleys or plains adjacent thereto, are in the regularly irrigated region.

THE REGULARLY IRRIGATED AREA.

This is the area where success in fruit growing is conditioned upon irrigation and where rainfall is too uncertain or too limited in amount to warrant dependence upon it as a source of moisture. This region is quite clearly defined on the basis of actual practice in the regions of eastern Washington, southwestern Idaho, California, and Arizona indicated on the map. Eastern Oregon and Nevada are included chiefly on a theoretical view of similar natural conditions, for very little fruit is yet produced in those areas. The eastern extension of the region is intended to be indefinite, as it evidently passes beyond the scope of this inquiry.

RELATION OF PHYSICAL FEATURES TO IRRIGATION PRACTICE.

A table is given on page 12 which contains the data upon which the districting shown in the map was made. In this table it has been decided, for the sake of brevity, to omit the regions of large rainfall on the west side of the Cascade Mountains in Washington and Oregon and of the Coast Range in northern California, except as certain sections may approach the dividing line between humid and arid conditions and thus become valuable for comparison. The elevated regions are also omitted from consideration because no fruit of commercial account is grown above an elevation of 5,000 feet, and comparatively little above 4,000 feet. The question of hardy fruits for greater elevations has hardly arisen in the Pacific States because of the immense area of available land at lower levels. In this, and other tables to follow, the arrangement of localities will be from north to south.

The first table is intended to present, with the exceptions noted above, a general view of conditions under which irrigation is or is not practiced within the area shown in the accompanying map. Information was requested from fruit growers, first, as to elevation, both above sea level and above the local river bottom or low plain; second, the exposure, where slopes were involved; third, character of soil upon which fruit was grown; and fourth, the local rainfall. Where reported rainfall differs from that shown by the accurate records of the Weather Bureau, it is sometimes due to slightly different location and sometimes, perhaps, to mistakes in observation. However this may be, the reports present the best estimates the fruit growers could make from the data at command. The fifth inquiry was as to the local irrigation practice. The replies represent different phases of the irri-

gation of deciduous fruits.[a] The fruits of the citrus family and others of semitropical regions are not included. On the Pacific coast these semitropical fruits are nowhere grown without irrigation, and they are therefore excluded from consideration, except where specifically mentioned, and they will be so mentioned only in connection with districts where the deciduous fruits are grown without irrigation. Reference to small fruits is of similar significance. Almost everywhere the berry season is extended by use of water in the dry part of the year, while the deciduous orchard fruits adjacent may grow satisfactorily without it. On the Pacific coast the term "small fruits" does not include grapes or cherries.

A summary of the data relating to topography, soil, rainfall, and irrigation practice is given in the table following.

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[a] The term "deciduous fruits" is in common use in California to designate fruits grown on deciduous trees, and comprises the ordinary garden and orchard fruits of the temperate zone.

Summary showing topography, soil, rainfall, and irrigation practice in Pacific coast regions.

State and region.	Elevation above—		Exposure.	Soil.	Rainfall.	Irrigation practice.
	Sea level.	River bottom.				
IDAHO.	*Feet.*	*Feet.*			*Inches.*	
Latah County	1,000–2,600	50	N. and E.	Clay loam	16–24	No irrigation.
Potlatch Valley	2,700	175–400	Various	Deep clay loam	30	Do.
Lewiston Valley	640–740	20–300	N. and E.	Alluvial, volcanic	11–20	All fruits irrigated.
Clearwater Valley	640	15–100	Various	Sandy, alluvial	11–20	Do.
Weiser Valley	2,200	50–200	N. and S	Granitic loam	[a]	Do.
Payette Valley	2,200	10–60	N	Alluvial, sandy	[b]	Do.
Boise Valley	2,200	10–30	N	Sagebrush, sandy	6.5–25	Do.
Blackfoot	4,125	12	N. and E.	Alluvial, sandy	9.5–12	Do.
WASHINGTON.						
Farmington	2,600	20–200	Various	Light and heavy loams	24	No irrigation.
Palouse County	2,300–2,600	1,000–2,000	N. preferred	Clay loams	12–28	Do.
Saltese Lake	2,000	100–500	Various	Light and heavy loams	18.5	Do.
Moran Prairie	2,000	200–300	Various	Sandy loam	20	Do.
Yakima Valley	900	20–150		Light, volcanic ash	3–6	All fruits irrigated.
Ahtanum Valley	1,000	300	E	Sandy	2–3	Do.
Wenatchee	600–1,600	60	N	Sand and volcanic ash		Do.
Wilbur	890	20	NE	Light and heavy loam		All except apples irrigated.
Orchard Valley	830	75	N. and W	Sand and volcanic ash	19	All fruits irrigated.
Touchet Valley	2,000	2–10	Level	Volcanic, dark loam	17	Do.
OREGON.						
Hood River	200–2,000	50–1,500	NW. and NE	Clay and sandy loams	35	Small fruits irrigated.
The Dalles	160–1,000	35–800	N. and E.	Deep dark-brown loam	15.6	Do.
Do	160	25	N	Light sandy loam	15.6	All fruits irrigated.
Summerville	2,800–3,000	300	S	Black alluvial loam	17	No irrigation.
Milton	2,080	20			16	All fruits irrigated.
Pendleton					18–30	No irrigation.
CALIFORNIA.						
Central coast.						
Ukiah Valley	800	10–100	Level	Sandy loam	35–60	Small fruits only.
Napa Valley	500	300	Various	Heavy to light loams	28	Do.
Sonoma Valley		30	Level	Alluvial loam	25–30	Do.
Dry Creek Valley	500–1,500	10–1,000	Various	do	40–60	Do.
Mark West Valley	200	20–100	Various	Dark gravelly loam	35	Do.

Alhambra Valley	500	20–300	Various	Black loam	21	Citrus and small fruits only.
Concord Valley	760	(c)	Mostly W	Heavy loam	20	Do.
Alameda Valley	50–100	(c)	Level	Light and heavy loams	16	Do.
Santa Clara Valley	600	(d)	S	Reddish loam		No irrigation.
Do	700	500		Clay loam	25	Do.
Do	75–2,550		Various	Heavy loam	12	Small fruits only.
Do	85–100	10	Level	Loam and sediment	20	Pears, plums, cherries, peaches.
Do	80–100		Level	do	16	Irrigation to 20 inches.
Do	150–300	15–30	N	Light and heavy loams	16	Plums, apricots, peaches.
Do	90–300	10–200	Various	Dark sediment and loam	15–20	Cherries and small fruits.
Santa Cruz Mountains	1,200–3,000	(e)	Various	Upland loams	36–60	Small fruits only.
Do	1,300	(e)	S. and E	Alluvial and sandy loam	40	No irrigation.
Do	1,500–2,000	250	Various	Deep gravelly loam	25	Small fruits only.
Do	1,500–2,500	800–1,800	N. and S	Clay and sandy loams	60	No irrigation.
Do	1,700–2,300	(e)	Various	do	45–50	Small fruits only.
Pajaro Valley	15–40	15	Level	do	20	Do.
Do	200	20–30	Level	do	24–30	Do.
Do	30–100	20–70	Level	Heavy black and light loam	10–30	Do.
Carmel Valley	20–2,000	150–1,500	S	Sandy loam	13.5	All fruits irrigated.
Creston	1,200	700	NE	Alluvial and ridge	16	Small fruits only.
Moro Bay slope	350	200–300	Various	Clay and gravelly loams	17	No irrigation.
Interior valleys and foothills.						
Redding region	600	(f)	Level	Deep alluvial	35	No irrigation.
Happy Valley			Plateau	Red over hardpan		All fruits irrigated.
Red Bluff	350	200–300		Heavy clay loam	25	No irrigation.
Chico	200	25	E	Sandy loam	28	Do.
Yuba City district	28–30	6–12	Level	Alluvial	20	Citrus and small fruits.
Colusa	60	10–15	Level	Alluvial over clay	12	Winter irrigation.
Vaca Valley	175–500	15–300	Various	Heavy and light loams	30	No irrigation.
Pleasants Valley	175–500	15–300	S. and SE	do	25	Do.
Do	600	400	Ridge	Decomposed sandstone	25	Do.
Sacramento Valley	50	20–30	Level	River bank alluvial	15	Do.
Do	33	10	Level	do	20	Do.
Do	35	20	Rolling	Gravelly over bed rock	20	All fruits irrigated.
Do	50	10–15	Level	Clay and sandy loams	18	Olives and grapes.
Ione Valley	140		S	Black loam	20.6	No irrigation.
Smithson, Shasta County	1,100	20–100	S	Light and heavy loams	45	Small fruits.
Whitmore	1,600–2,500	400–800	S. and SW	Red and gray clay loam	40	All fruits irrigated.
Nevada County	1,000–2,500		Various	Clay and sandy loams	35–45	Do.
Placer County	900–3,500	(e)	Various	Red and black loams	25–35	Do.
Amador County	1,000–3,000		S	do	18	Do.
San Joaquin Valley	300	30–40	Level	Light loam	10.6	Do.
Do	300		Level	Red sandy loam	10	Do.
Do	200		Level	Light sandy loam	8	Do.
Do	240	6–20	Level	Alluvial, sandy	7	Do.
Do	390		Level	Alluvial, water 8 feet	10	Irrigated by underflow.
Do	461	50	W	Clay loam	10	All fruits irrigated.
Do	415		Level	Heavy and light loams	4	Do.
Do	800	20–150	Various	Sandy loam	9	Irrigated by underflow.

[a] Few showers. [b] Very light. [c] Plain. [d] Hillside. [e] Various. [f] Creek bottom.

Summary showing topography, soil, rainfall, and irrigation practice in Pacific coast regions—Continued.

State and region.	Elevation above— Sea level.	River bottom.	Exposure.	Soil.	Rainfall.	Irrigation practice.
CALIFORNIA—continued.						
Mountain region.	*Feet.*	*Feet.*			*Inches.*	
Modoc County	4,300			Sandy loam	20–27	All fruits irrigated.
Madera County	2,000–4,000			Granitic loam	25–30	Do.
Tuolumne County	2,800–4,000		N	do	30–40	Do.
Mariposa County	3,000	20–100	E. and N	do	20–40	Do.
Do	4,500	10–100	N., S., and W	Heavy and light loams	40–50	Small fruits irrigated.
Inyo County	5,000–7,000	100	S. and E	Sandy loam	2–6	All fruits irrigated.
Southern California.						
Carpenteria Valley	20–900	20–900	S. and E	Dark loam	15–18	Citrus and small fruits.
Ventura coast plain	5–15		Level	Heavy and light loam	16	Do.
Ojai Valley	500	150	Level	do	20	Do.
Do	1,100	300	S	do	20	Do.
Do	1,350	500	S	Heavy loam	15–20	Do.
Do	1,450	25	N. and S	Alluvial and sandy	16–25	Do.
Fillmore district	700		S	Medium loams	17	Do.
Simi Valley	1,000	20–50		Clay and sandy loams	15	Do.
Piru Valley	700–1,000	300	Various	Sandy and gravelly loams	12–15	All fruits irrigated.
Antelope Valley	2,500–3,300		Various	Decomposed granite	9	
San Fernando Valley	800	25–300		Light and heavy loams	12	Irrigated for deciduous fruits.
Do	559	25–100	N	Sandy loams	17	Do.
Cahuenga Valley	650	125	Various	Light and heavy loams	20	Citrus and small fruits.
Pasadena	700–800		Various		12	Do.
Sierra Madre	1,000	400	S. and E	Decomposed granite	12–14	Citrus fruits.
Alhambra	600	20–300	SE. and W	Gravelly loam	13–17	Citrus and small fruits.
Do	500–1,000	300–700	S. and E	Decomposed granite	15	Deciduous fruit better with irrigation.
San Gabriel	600		S	Black and sandy loam		Citrus fruits and walnuts.
El Monte	300	10	Level	Sediment	17	Walnuts except wet years.
Duarte	500–680		S. and E	Light and heavy loams	12–24	Citrus fruits irrigated.
Do	1,000		S	Decomposed granite	10	Do.
Glendora	1,000		S	do	20	Do.
Do	1,000–1,500		S. and E	Fine sandy loam	20	Do.
Azusa	600			Sandy loam	12–20	All fruits irrigated.
Monrovia	2,500	30		do	11	Do.
San Dimas	1,000		S. and E	Fine sandy loam	20	Citrus fruits irrigated.
Covina	600	300	S. and E	do	17	All fruits irrigated.
Pomona	862		SW	Light and heavy loams	18	Do.
Do	700–1,500			do		Do.
Do	800			Sandy loam	17	Citrus and walnuts.

Claremont	1,125–1,225	600	S		20	Citrus fruits.
Do	1,134	345	S	Light and heavy loams	14.5	All fruits irrigated.
Whittier	450	200	W	Heavy loam	18	Citrus and walnuts.
Do	200–400	1–300	W	Dark loam	15	Do.
Rivera	25	10	Level	Dark, deep loam		Little or no irrigation.
Anaheim	175		Level	Clay and sandy loams	12	All fruits irrigated.
Santa Ana	100	24	Level	Various	8	Do.
Orange	200–300	20	SW	Heavy and light loams	5–20	Do.
Fullerton	250	20–70		do	15	Do.
Ontario	950–2,250	400–1,700	S	Decomposed granite	20	Citrus fruits irrigated.
Chino	900–1,000	200	S	Heavy and light loams	17	Do.
Rialto	1,200	1,000	SE	do	12–16	All fruits irrigated.
Highland	1,300	10–400	S	do	10–18	Do.
Redlands	1,500–2,000			Dark chocolate loam	10–30	Citrus fruits irrigated.
Bloomington	1,100	200		Sandy loam	15	All fruits irrigated
East Riverside	1,050–1,400	50–300	N. and W	Red and brown sandy loam	12	Do.
Riverside	800–1,000	150	N. and W	Light and heavy loams	12	Do.
Do	950	200	S. and W	do	10	Do.
San Jacinto	1,500	100–150		Sandy loam	8–10	Do.
Hemet	1,600–1,800			Deep brown loam	15	Do.
Elsinore	1,340	30–200	SE	Sediment and granitic	10–12	Citrus fruits irrigated.
Fallbrook	1,500	500	N. and S	Upland loam	17	All fruits irrigated.
Palomar Mountain	3,500–5,000	3,000	N. and W	Granitic loams	40	No fruits irrigated.
Valley Center	1,500	200–300	N	do	18–20	Citrus fruits irrigated.
Escondido Valley	750	10–150	Level	Redland dark	12–15	Do.
San Marcos Valley	600–700	10–100		Clay loam	8–15	Do.
Poway	500	10–15	Level	Light and heavy loam	15	Small fruits irrigated.
Julian	4,225			Deep loams	25–30	No fruits irrigated.
Flinn Valley	1,400	100	SW	Light and heavy loams	15–20	Citrus and small fruits irrigated.
El Cajon	350			Alluvial and red loams	12	All fruits irrigated.
Chula Vista, La Mesa	10–500		Various	Red granitic over clay	10–15	Do.
Linda Vista	40–570		W	Red loam, some clay	8.5	Do.
ARIZONA.						
Verde Valley	3,500			Clay and sandy loams	11.44	Do.
Lower Lyon Creek	4,500	5–10	E	Rich alluvial	17	Do.
Salt River Valley	1,200	30–150	Level	Clay and sandy loam	7.5	Do.
Yuma	240	80	Level	Sandy loam	3	Do.
NEVADA.						
Washoe Valley	5,200	50	SE	Black leaf mold and sand	24.68	Do.

The following generalizations seem to be warranted by the data given in the table:

RELATION OF ELEVATION AND EXPOSURE TO IRRIGATION.

It is clear that elevation does not alone determine the necessity for irrigation. The table shows it to be practiced from 20 feet above sea level on the coast plain of Orange County, Cal., to 5,000 feet above sea level in Inyo County, Cal., and in southeastern Idaho. Nor is height above local river bottoms a ruling factor, for it is resorted to both on river bottoms and several hundred feet above them on the slopes of adjacent foothills. The same is true of exposure. The table shows irrigation on all slopes and on lands practically flat. Both exposure and elevation are local factors of some moment, however, when they coincide with other conditions, as will be shown later.

RELATION OF SOIL TO IRRIGATION.

The desirability of irrigation is unquestionably, in many cases, conditioned upon soil depth and character. This relation has received careful attention from soil physicists, and, although an understanding of it involves problems of plant growth and the movement of water in soils, the leading facts are available in popular form.[a]

An examination of the data in the table shows the prevalence of irrigation in localities where fruits are grown on light loams, whether the soils have resulted from local disintegration of rocks or have been transported to their present locations. This is merely wider proof of the fact of ordinary observation that, other things being equal, the coarser and less retentive the soil the greater the necessity for irrigation; but the fact is strikingly presented in a number of cases. One grower at The Dalles, Oreg., is located on an upland loam, dark brown, formed of decomposed basalt at the base of slopes from 10 to 50 feet in depth—a soil holding moisture well and producing fruits without irrigation. Another grower has reclaimed a sand flat along the Columbia River by irrigation, and is growing tree fruits profitably on land which originally was hardly worth $1 an acre, but which his work has made worth one hundred times that amount. Here the character of the soil was an important factor in determining the necessity for irrigation. Another striking contrast is shown in four neighboring localities in the Sacramento Valley, California. Elevation, rainfall, and exposure are similar, yet in two cases irrigation is practiced and in two it is not. The explanation here is the occurrence in the two

[a] Relation of Soils to Climate, U. S. Dept. Agr., Weather Bureau Bul. 3. Water as a Factor in the Growth of Plants, Yearbook U. S. Dept. Agr., 1894, p. 165. Some Interesting Soil Problems, Yearbook U. S. Dept. Agr., 1897, p. 429. The Movement and Retention of Water in Soils, Yearbook U. S. Dept. Agr., 1898, p. 399. The Mechanics of Soil Moisture, U. S. Dept. Agr., Division of Soils Bul. 10.

irrigated districts of an impervious hardpan, locally called "bedrock," which is so near the surface that the shallow layer of soil can not retain moisture enough to maintain growth and fruiting in the dry season.

RELATION OF RAINFALL TO IRRIGATION.

The amount of rain and the time it falls are clearly the most important factors in determining the necessity for irrigation. Absence of rainfall makes a desert of the richest soils at all elevations and at all exposures. Its only remedy is irrigation. But there are degrees of poverty in rainfall, and thorough tillage will often lessen the ill effects of a scanty supply, so that an oasis may be made to appear without water beyond that supplied from the clouds. This is the triumph of tillage in the arid region which is to be considered in another connection.

The line between adequate and insufficient rainfall can not be closely drawn. It is true that there is a striking general agreement between the boundaries of the nonirrigated, partially irrigated, and wholly irrigated regions on the map which accompanies this report and the boundaries of a map showing amounts of rainfall, but there would appear, on a closer examination of the facts as presented in the tabulation above, very marked departures of irrigation boundaries from rainfall boundaries, so that if one should undertake to determine the need of irrigation by the local rainfall figures alone and proceed to investment on that basis, he would be quite likely to lose his time and money. This has already been suggested in speaking of the relations of soils and irrigation.

It is obvious that there must be somewhere a point at which the rainfall is insufficient for the needs of crops and another point beyond which it becomes ample or even excessive. But these points are not fixed. They vary with the character of the crop, the soil, exposure, the distribution of the rainfall through the year, and the local temperatures which fix the length of the growing season. With reference, however, to the growth of common orchard fruits, which are alone in view in this discussion, the table shows that irrigation is not resorted to at a number of points where the local rainfall sometimes is as low as 15 or 16 inches, but that with less than that amount, unless the soil receive additional moisture by underflow, it is essential. On the other hand, irrigation is regularly practiced in some localities where the rainfall sometimes rises to 45 inches. The table does afford, however, ample evidence that, under average conditions of soil depth and retentiveness in the region under consideration, the amount of rainfall which may be considered adequate for orchard trees under good cultivation is about 20 inches. So definitely is this amount fixed in the minds of some California growers as meeting the needs of the tree

for satisfactory growth and fruitage that, when rainfall is less than that amount, irrigation is at once resorted to to supply the shortage. An interesting confirmation of this view is found in the reports from growers in the humid region along the coast, which comprises the unirrigated portion on the accompanying map.[a] In the Sound region of Washington the rainfall is about 25 inches, and correspondents state that although irrigation is not practiced it "might be beneficial." The same opinion is expressed by growers in the Rogue River Valley in southern Oregon, where rainfall is but little above 20 inches and conditions resemble those in the valleys of northern California.

INTERRELATION OF ELEVATION, EXPOSURE, SOIL, AND RAINFALL.

The great variety of conditions under which irrigation is found either desirable or unnecessary is intelligible only upon consideration of the interrelation of elevation, exposure, soil, and rainfall. In northern Idaho and northeastern Washington there is an elevated region of rolling land with an average rainfall of a little above 20 inches, a clay loam often of considerable depth and underlaid by clay and naturally well drained, yet retentive of moisture by virtue of its fine texture resulting from decomposition of basaltic rock. Irrigation is found unnecessary. The depth and character of the soil and its slope and exposure combine to insure maximum duty of rainfall. In adjacent valleys of both Idaho and Washington there are lands but little nearer sea level and with only a little less rainfall, but with soil of alluvial character or resulting from volcanic action or decomposition of granite, all being coarse, light, and nonretentive. Here the character of the soil reduces the duty of rainfall, and regular irrigation is found essential to the growth of fruits.

At lower levels, both in Idaho and Washington, are found fruit regions where manifestly deficient rainfall accompanies deep though nonretentive soil, higher heat, and greater evaporation, and desert conditions are only relieved by ample and systematic irrigation. And yet there occur also exceedingly fine soils in some portions of the desert regions which are very retentive of moisture and would secure the highest duty from rainfall if there were enough of it to enable them to act effectively. Upon such soils a maximum duty of irrigation water is secured, and the amount required is relatively small. The occurrence of these conditions is not always to be measured by large areas. They are found in different parts of the same region, in some cases, in fact, within the limits of the same farm, making an understanding of their influences and effects all the more essential.

In California similar instances of the interrelation of soil, rainfall, exposure, and local climate, and their influence upon horticultural

[a] These reports are omitted from the table.

practice with reference to irrigation, could be cited in great number. A few must suffice.

On the famous river-bank fruit land of the Sacramento Valley, with loams of great depth and good retentiveness, and with an average rainfall of approximately 20 inches, irrigation is resorted to only in years of minimum rainfall, when the precipitation is perhaps only about half the average. At nearly the same level, as already cited, where the soil is shallow and overlies hardpan, regular irrigation is required. But still more marked contrast is found in the foothills within sight of these valley fruit lands, where with twice the average rainfall irrigation must begin early in the summer and continue until autumn is well advanced, because, first, the slope is so rapid that much rainfall is lost by run off; second, the soil is too shallow above bed rock to hold much water. Even here, however, there comes in a local variation of measurable effect. When the soil lies upon vertical plates of bed rock much water is retained between them and is capable of being reached by tree roots, while soil lying upon flat plates of rock has no such subterranean reservoir. In the foothill region there also occurs exceptional exposure from slopes facing the midsummer sun in an atmosphere whose dryness is but slightly ameliorated by the influence of air currents from the coast.

In the valley and foothill contrast, just cited, the unirrigated valley looks up to the irrigated foothills. There are also places where unirrigated hill slopes look down upon irrigated valleys. The uplands of San Diego County are nearer the coast than those above the Sacramento Valley. They, too, have a rainfall usually ample for deciduous fruits suited to their elevation. Their rolling plateaus of deep soil, free from excessive heat and evaporation which occur on highlands farther inland and 500 miles farther north, produce very successfully without irrigation. In this region, however, the rainfall in the valleys below is often less than the needs of even deciduous fruit trees, and waters flowing from mountain snows through a region of unirrigated uplands must be used to irrigate them.

Still another striking contrast, and one involving another and wholly different factor, is found in the San Joaquin Valley. Near Visalia, 2 feet above river bottom and 4 feet above the surrounding plains, there is a large area of deep alluvial soil with much decayed vegetable matter. The land is moistened by underflow from the river, and, though the rainfall is but 7½ inches, deciduous fruits are grown without irrigation. In the same county, and only 18 miles distant, there are areas of rich loam mixed with granitic sand 16 to 18 feet deep. In this locality, though the rainfall is 11¼ inches, irrigation is practiced freely, as the loss of moisture in summer is very great.

Many more quite as striking and effective illustrations might be given of the impossibility of accurate generalization on geographical,

or purely meteorological data alone. Evidently, however, it is clear that the need of irrigation is conditioned upon so many factors of earth, air, and water, as well as upon the needs of the plant grown and the system of tillage, that any wise decision regarding the needs of a particular locality can be reached only after considering and weighing all elements entering into the problem.

RELATION OF TILLAGE TO IRRIGATION.

Tillage, particularly during the dry season of the year, under some conditions, directly determines the need of irrigation, and is to a certain extent, as the popular phrase goes, a substitute for irrigation. Under all conditions surface tillage, by promoting conservation of soil moisture, is determinative of the actual duty of water, whether it be from rainfall or irrigation. The effect of frequent surface tillage has been accurately determined by investigation and experiment, both in humid and arid regions.[a] These experiments fully support the view taught by the experience of about half a century in California, in accordance with which thorough winter and summer tillage has been so widely practiced in the arid section as an essential to successful fruit growing. There are, however, some conditions in which clean cultivation during the season of highest heat may not be the best practice, as will appear later.

The relations of tillage to soil moisture include both reception and conservation. For the reception of moisture, deep work with the plow, and sometimes with the subsoiler also, is almost indispensable. To retain this moisture and to prevent, as far as possible, its escape into the thirsty air of the arid region by surface evaporation, less depth and more thorough surface pulverization are required. Recent practice has been tending toward deeper summer cultivation, so that 5 or 6 inches of loose, finely divided soil is now obtained where formerly half that depth was considered adequate. It has also been shown that frequent stirring of this fine surface layer checks evaporation, even when no water is applied to compact the surface or where no weeds grow to draw upon the soil moisture. In a word, the aim of tillage in the arid region, so far as it relates to moisture supply in the soil, consists in opening the soil to rain, or to irrigation, and in subsequently closing it to evaporation. How this is done by the different growers over the large area included in this report is shown in the table following.

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[a] Wisconsin Sta. Rpt. 1894, p. 279; California Sta. Rpt. 1897–98, p. 57.

Summary showing cultivation practice in connection with irrigation in Pacific coast region.

Name and locality.	Soil.	Irrigation.	Cultivation.
IDAHO.			
W. A. Sample, Blackfoot.	Sandy and gravelly; alluvial bottom.	All fruits irrigated....	A good cultivation after each irrigation.
Edgar Wilson, Boise City.	Sandy, sagebrush, well drained.	.....do................	Cultivation after each irrigation; more cultivation replaces some irrigation.
A. McPherson, Boise City.	Dark and sandy loams.	.....do................	One plowing and sixteen to twenty cultivations—not later than August 15.
Robert Millikin, Boise City.	Volcanic ash and decomposed rock.	.....do................	Four plowings and six cultivations—less irrigation, more frequent cultivation.
W. W. Wells, New Plymouth.	Clayish alluvial; little sand.	.....do................	Cultivation every two weeks to August 1; only once or twice after that.
W. G. Whitney, Payette	Sandy loam..........	.....do................	Two to four cultivations.
George Little, Caldwell	Sandy, sagebrush....	.....do................	Four cultivations.
T. C. Galloway, Weiser.	Bench, granitic loam.	.....do................	Do.
A. F. Hitt, Weiser......	Bench, sandy loam...	.....do................	One cultivation before and one after each irrigation.
L. A. Porter, Lewiston.	Rich, sandy, alluvial.	.....do................	One plowing and one deep cultivation after each irrigation.
H. A. Russell, Kendrick.	Black sandy and clay loams.	Little or no irrigation.	One plowing and three cultivations.
F. A. Huntley, Moscow	Clay loam............	No irrigation.........	One plowing and three or four cultivations
WASHINGTON.			
C. Risteau, Moran Prairie.	Sandy loam..........	.....do................	One plowing and two cultivations.
Jason Whinery, Moran Prairie.	Alluvial bottom and upland loams.	.....do................	Two plowings followed by harrowings
D. W. Bridgman, Latah	Clay and sandy loams.	.....do................	Plow once and harrow May 1; cultivate June 1; hoe balance of the season.
W. E. Schneider, Latah	....	.....do................	Nine cultivations with rolling harrow, three at each working, in April, June, and August.
F. A. English, Farmington.	Clay and sandy loams.	.....do................	One plowing, one harrowing, and three cultivations not later than July 15.
J. A. Balmer, Pullman.	.....do................	.....do................	Six cultivations, securing dust mulch, and then keeping down weeds.
Theo. Smith, Colfax ...	Upland loams........	.....do................	Six to twelve cultivations.
George Ruedy, Colfax.	Moist clay loam......	.....do................	Three or four cultivations not later than August 15.
Jos. De Long, Endicott.	Clay and sandy loams.	.....do................	Two or three cultivations.
E. H. Hanford, Oakesdale.	Upland loam.........	.....do................	Four to eight cultivations.
A. L. Smith, Spokane..	Clay and sandy loams.	Small fruits only.....	Two plowings and two cultivations.
E. P. Gilbert, Spokane.	.....do................	No irrigation.........	Two or three cultivations not later than September.
J. H. Friedlander, Wilbur.	Light and heavy loams.	All except apples....	One plowing and five or six cultivations.
Allen Emerson, Creston.	Sandy loam and volcanic ash.	All fruits irrigated...	Three cultivations.
J. N. James, Waitsburg.	Volcanic loam, clay subsoil.	.....do................	Cultivate after each irrigation, June to August.
Matthew Stanton, Middle Ahtanum.	Sandy loam..........	.....do................	Three times in spring with shovel plow; afterwards twice with cultivator; then hoe as weeds start.
C. S. Simpson, North Yakima.	Light loam...........	.....do................	Three to five cultivations.
T. F. Dice, Prescott....	Loose loam..........	.....do................	Two plowings and two cultivations.
F. E. Thompson, Parker.	Light and heavy loams.	.....do................	Two plowings, three or four harrowings. Old trees in clover.
Elias Marble, Wenatchee.	Volcanic ash and sand	.....do................	One plowing alternate years; six cultivations each year.
E. Keohler, Wenatchee	Basaltic loam........	.....do................	Three cultivations.
C. Robinson, Chelan...	Sandy loam..........	Few trees irrigated...	Cultivate every two or three weeks until August.
H. H. Spader, Chelan..	Loam, bench lands...	No irrigation, but moisture is short.	Deep plowing in fall followed by three cultivations in spring and summer.
H. C. Cook, White Salmon.	Sandy, gravelly, and clay loams.	No irrigation.........	One plowing and two cultivations.

Summary showing cultivation practice in connection with irrigation, etc.—Continued.

Name and locality.	Soil.	Irrigation.	Cultivation.
OREGON.			
S. A. Miller, Milton		All fruits irrigated	One plowing and three cultivations after irrigations.
Thomas Spence, Milton.		do	Six cultivations.
H. W. Oliver, Summerville.	Black alluvial	No irrigation	Plowing and cultivating three times, May to August.
C. Walters, Athena		do	Clean cultivation.
R. H. Webber, The Dalles.	Light loam	Small fruits only	One plowing and six to ten cultivations for orchard.
Seufert Bros., The Dalles.	Sandy river bottom	All fruits irrigated	Clean cultivation.
E. L. Smith, Hood River.	Sandy and clay loams.	Small fruits only	One plowing and harrowing and frequent cultivation until August.
W. Dimmick, Hubbard	Black and red loams	Might be of advantage.	One plowing and clean cultivation nearly until fruit ripens.
E. R. Lake, Corvallis	Basaltic loam	Occasional for small fruits.	One plowing, disking and harrowing six to ten times.
R. C. Brown, Roseburg	Sandy and gravelly loams.	Profitable for small fruits.	Clean cultivation.
J. R. Casey, Ashland	Granitic loam over clay.	No irrigation	Do.
Max Pracht, Ashland	Granitic loams	For late berries	One plowing and three cultivations.
C. F. Stewart, Medford	Deep red and black loams.	No irrigation	Plow in March and harrow three times; cultivate two to four times, not later than July 15.
CALIFORNIA.			
Coast valleys.			
L. M. Babcock, Ukiah	Light and heavy loams.	Small fruits only	Clean cultivation for orchard.
E. W. King, Ukiah	Black gravelly loam	do	Do.
A. E. Burnham, Healdsburg.	Sandy and gravelly loam.	No irrigation	Two plowings; four to six cultivations, followed by clodmashing both ways.
J. R. Little, Mount Olivet.	Dark, gravelly loam	do	Two plowings, followed by harrowing; clodmashing; two cultivations.
W. H. Pepper, Petaluma.	Clay and sandy loams.	do	One or two plowings and two or three harrowings.
Robert Hall, Sonoma	Alluvial over clay	do	Two plowings with harrow after second; disk followed by chain harrow, roller, or clodmasher.
H. Baskerville, St. Helena.	Rich, deep, loose loam	Small fruits only	For orchard and vineyard plow and cross plow, with harrowings; cultivate to keep surface loose.
E. F. Cook, Napa	Heavy valley loam	No irrigation	Two plowings and eight cultivations.
George Husmann, Napa	do	Citrus fruits only	One plowing, two cultivations with disk.
Leonard Coates, Napa	Well-drained loam	No irrigation	One plowing followed by disk and other cultivators.
John Swett & Son, Martinez.	Chiefly black loams	do	Two plowings and six cultivations with disk, cutaway, etc.
B. H. Upham, Martinez.	Heavy valley and light hill loams.	Citrus fruits only	Two plowings followed by harrow; cultivators and hand hoeing afterwards.
F. Barbour, Clayton	Sandy and clay loams.	do	One plowing, two cultivations.
J. C. Shinn, Niles	Heavy and light alluvial loams.	Citrus fruits only, except in dry years.	Plowing and harrowing spades and clodmasher—four to eight workings in all.
E. M. Ehrhorn, Mountainview.	Heavy and light loams	Irrigation increasing	Two plowings and harrowings; roll and cultivate until July 15.
A. Block, Santa Clara	Sedimentary loam	Irrigation according to amount of rainfall.	Two plowings and eight cultivations.
W. Pfeffer, Gubserville	Retentive clay loam	No irrigation	Two plowings and three cultivations.
S. P. Sanders, San Jose	Heavy and light sedimentary loams.	Winter irrigation to supplement rainfall.	Two plowings and disk as needed to keep clean and loose.

Summary showing cultivation practice in connection with irrigation, etc.—Continued.

Name and locality.	Soil.	Irrigation.	Cultivation.
CALIFORNIA—cont'd.			
Coast valleys—Cont'd.			
F. M. Righter, Campbell.	Heavy and light loams.	Irrigation when rainfall is light.	One plowing; cultivation twice a month, March to June.
A. C. Fuller, Evergreen	.....do	Irrigation for cherries and berries; other fruits if necessary.	One plowing and three to six cultivations.
H. Hoops, Wrights	.....do	Irrigation for small fruits only.	One plowing, two to four cultivations.
E. F. Adams, Wrights	.....do	.....do	Two plowings and three cultivations.
W. H. Aiken, Wrights	Clay and sandy loams.	No irrigation	Two plowings, and harrow frequently until fruit nearly matures.
R. W. Eaton, Watsonville.	Black and sandy loams.	Irrigation for small fruits only.	Two plowings, two harrowings, two cultivations.
J. A. McCune, Watsonville.	.....do	No irrigation	One plowing and three cultivations.
Edward Berwick, Monterey.	Sandy loam	Chiefly in winter for orchard.	Two plowings and often six cultivations.
J. V. Webster, Creston	Alluvial and ridge loams.	Only for small fruits	Two plowings and two cultivations.
J. A. Girard, Cayucos	Deep loams	No irrigation	Two plowings and cultivations.
Elwood Cooper, Santa Barbara.	Heavy and light loams.	Irrigation for citrus fruits.	Plow twice; cultivate about five times.
O. N. Cadwell, Carpenteria.	.....do	.....do	Clean cultivation.
Russell Heath, Carpenteria.	Clay and sandy loams.	.....do	One plowing, followed by clean cultivation.
J. B. Alvord, Oxnard	Heavy and light loams.	For small fruits only	Two plowings and six cultivations.
H. J. Dennison, Nordhoff.	Alluvial and sandy loams.	For citrus fruits only.	One plowing, three cultivations, and hoeing around trees, using harrow after each rain.
L. C. Gridley, Nordhoff.	Clay loam	.....do	One plowing and cultivation after each irrigation.
E. S. Thacher, Nordhoff.	.....do	Citrus fruits; others would be benefited.	Plow once, cultivate three times between irrigations; unirrigated lands cultivated all the season.
N. J. Bond, Nordhoff	Clay and sandy loams.	No irrigation for deciduous fruits.	One plowing with cultivator and harrow after each rain.
R. Dunn, Fillmore	Medium loams	Citrus fruits, but all would be better for it.	Three or four cultivations.
J. C. Scott, Simi	Clay and sandy loams.	No irrigation	One plowing and four to eight cultivations.
L. F. Gay, Piru	Dark, also sandy, and gravelly loams.	Irrigation for citrus and once for apricots and peaches.	Cultivate once a month or more after each irrigation.
L. T. Garnsey, San Fernando.	Clay and sandy loams.	For citrus fruits.	One plowing; three cultivations; one harrowing; one leveling.
C. Forman, Toluca	Sandy loam	None for deciduous fruits.	Two plowings and frequent cultivations.
O. E. Roberts, Cahuenga.	Heavy to light loams.	.....do	About eight cultivations.
M. C. Graham, South Pasadena.	Clay and sandy loams.	Citrus and small fruits.	Plow twice, cultivate once each month.
F. E. Gray, Alhambra.	Gravelly loam	.....do	Plow or cultivate after each rain or irrigation.
Pollard Brothers, Alhambra.	Clay and sandy loam and gravelly sediment.	.....do	Two plowings and twenty cultivations.
J. A. Graves, Alhambra.	Decomposed granite loam.	Citrus and small fruits and deciduous are better for it.	Plow four or five times and cultivate at least twice a month.
A. S. Bixby, Sierra Madre.	.....do	Citrus fruits	After each rain or irrigation plow in winter and cultivate in summer.
A. S. Chapman, San Gabriel.	Sandy loam	Citrus fruits and walnuts.	Four plowings and ten cultivations.
P. F. Cogswell, El Monte.	Sedimentary loam	Walnuts chiefly grown, irrigated in dry years.	Two plowings and four to six cultivations.
J. F. Branch, Artesia	Sandy loam	Underflow fatal to trees; good for grapes.	

Summary showing cultivation practice in connection with irrigation, etc.—Continued.

Name and locality.	Soil.	Irrigation.	Cultivation.
CALIFORNIA—cont'd.			
Coast valleys—Cont'd.			
W. W. Bliss, Duarte	Light and heavy loams.	Citrus fruits	Cultivation after each irrigation.
A. C. Thomson, Duarte.	Decomposed granite.	....do	Three plowings and six to eight cultivations.
H. D. Englehart, Glendora.	Granite and sandy loams.	....do	Plow fall and spring; frequent summer cultivation.
H. D. Briggs, Azusa	Sandy loam	All fruits irrigated	Heavy soil plow twice and cultivate six to ten times; sandy soil cultivation without plow.
A. B. Smith, San Dimas.	Deep sandy loam	Citrus and small fruits.	Two plowings and five to eight cultivations.
W. Q. Custer, Covina	Sandy loam	All fruits irrigated	Two plowings; cultivate both ways at least twice a month.
H. E. Cheeseboro, Covina.	....do	Citrus fruits	Two plowings; cultivation every six weeks.
J. R. King, Covina	Medium sandy loam	....do	Three winter plowings; summer and fall cultivation once a month.
J. W. Mills, Pomona	Light and heavy loams.	All fruits irrigated	Nine or ten workings in a year with plow, harrow, and cultivator.
Armstrong & Young, Pomona.	....do	....do	Two plowings and cultivations once or twice a month.
J. E. Packard, Pomona.	Sandy loam	Citrus fruits and walnuts.	Two plowings; cultivation once a month.
G. F. Ferris, Claremont.	Heavy and light loams.	All fruits irrigated	Plow both ways spring and fall; harrow after spring plowing; cultivate after each irrigation.
E. Squires, Claremont		Citrus fruits	About ten cultivations.
W. T. Strawbridge, Whittier.	Heavy loams	Citrus fruits and walnuts.	One plowing and six to eight cultivations.
I. H. Cammack, Whittier.	Dark heavy and light sandy loams.	....do	Four to eight cultivations.
L. L. Bequette, Rivera	Moist sandy land	Underflow generally adequate.	Plow twice and cultivate three times when no irrigation is used.
L. B. Benchley, Fullerton.	Light sandy and moist heavy loam.	Irrigation for all fruits save some peaches, apricots, and grapes.	One plowing and eight to twelve cultivations.
J. B. Neff, Anaheim	Heavy and light loams and sediment.	All fruits irrigated	Some years one plowing and six cultivations; other years twice as many.
F. S. Gates, Anaheim	....do	....do	Two plowings and cultivation after each rain or irrigation.
C. P. Taft, Orange	Medium and light loams.	....do	Cultivation after each irrigation.
A. D. Bishop, Orange	Sandy and gravelly loams; alluvial.	Citrus fruits; rainfall sometimes enough for deciduous.	Two plowings and eight to ten cultivations.
D. E. Smith, Santa Ana	Chiefly light loams	All fruits irrigated	Six to twelve cultivations.
J. W. King, Garden Grove.	Heavy, moist loam	Underflow too near surface for some fruits.	Spring and fall plowing; frequent summer cultivation.
Judson Williams, Fallbrook.	Heavy and light loams.	All fruits irrigated except in wet years.	Plow under winter growth and give frequent summer cultivation.
Jobes Brothers, Escondido.	....do	....do	One plowing; cultivate after each winter rain, and once a month in summer.
O. Hudson, Valley Center.	Black and red sandy loam over granitic subsoil.	Citrus fruits irrigated.	Plow once and keep fine surface by frequent working.
J. M. Hyne, Twin Oaks.	Clay loam and black lowland.	No irrigation	Plow in January and March; follow with six cultivations.
L. E. Kent, Poway	Light and heavy loams.	Small fruits irrigated and desirable for others some years.	One plowing and eight cultivations; more in dry years.
H. Culbertson, El Cajon.	Red foothill loam and alluvial bottom.	All fruits irrigated	One plowing and eight cultivations.
G. P. Hall, Lemon Grove.	Light and heavy loams in great variety.	....do	Cultivation every month or oftener.
J. P. Jones, Linda Vista.	Red, granitic loam	....do	One plowing and cultivation once a month.

Summary showing cultivation practice in connection with irrigation, etc.—Continued.

Name and locality.	Soil.	Irrigation.	Cultivation.
CALIFORNIA—cont'd.			
Interior valleys and foothills.			
S. C. Dondore, Lakeside.	Clay and sandy loams.	Citrus and small fruits irrigated.	Two plowings and twenty-five workings with harrow and cultivator.
L. Yates, Elsinore	Light granitic loam and dark sediment.	...do	Plow and cross plow and three or four cultivations.
J. W. Porter, Temescal.	Light loams	All fruits irrigated	Two plowings and cultivation once a month.
J. G. Reinhardt, San Jacinto.	...do	...do	Five or six cultivations.
F. A. Blake, Hemet	...do	...do	One plowing and about twelve cultivations.
Chase Company, Riverside.	Granitic loam	...do	One or two plowings; one or two cultivations in winter to kill weeds; cultivation after each irrigation.
W. E. Atwater, Riverside.	Red clay and sandy loams.	...do	One plowing and six or seven cultivations.
R. H. Howard, Riverside.	Brown clay and sandy loams.	...do	Cultivation each month after irrigation.
E. L. Koethen, Riverside.	Heavy and light loams.	...do	One or two plowings and cultivation after each irrigation.
James Boyd, Riverside.	Red clay and light loams.	...do	Two plowings and cultivation after each rain or irrigation.
Leland Lyon, Redlands	Deep, mellow chocolate loam.	...do	Two plowings and fifteen to twenty cultivations.
W. M. Bristol, East Highlands.	Medium heavy red loam.	...do	Plow in green crop in February, plow again in April, and cultivate after irrigation each month.
W. F. Grow, Messina	Heavy and light loams.	...do	Two plowings and cultivation twice a month.
W. S. Corwin, Messina.	Medium and light loams.	...do	Two plowings and eight cultivations.
C. J. Merryfield, Colton.	Red and brown sandy loams.	...do	Plow twice, harrow twice, cultivate twice to each irrigation.
E. Weston, Bloomington.	Light loams	...do	One or two plowings and cultivation every month.
J. S. McCracken, Rialto	Medium and light loams.	...do	One plowing and frequent thorough cultivation.
E. Rhodes, Chino	Light and heavy loams.	...do	One plowing and six to eight cultivations.
C. Frankish, Ontario	Decomposed granite and clay loams.	...do	Cultivate thoroughly once a month.
J. M. Hunter, Bakersfield.	...do	...do	Two plowings, three harrowings, and three cultivations.
J. T. Bearss, Porterville	Red clay loam	...do	One plowing and ten to twelve cultivations.
Thomas Jacob, Visalia.	Deep alluvial sediment.	Natural underflow	Two plowings and seven or eight cultivations.
C. J. Berry, Visalia	Alluvial with much vegetable matter.	...do	Cultivation every two weeks during growing period.
C. J. Berry, Lemon Cove.	Deep loam with granitic sand.	Apricots and citrus fruits irrigated.	Do.
J. A. Hill, Hanford	Sandy alluvial	All fruits irrigated	Two plowings and three cultivations.
J. S. McCormick, Easton	Light loam, "white ash."	...do	Two plowings and two or three cultivations.
Miss L. H. Hatch, Fresno.	Light loam	...do	Once with double plow, twice with single plow, twice with harrow, twice or more with cultivator.
George C. Roeding, Fresno.	Various light loams	...do	Two plowings and two cultivations in spring; one cultivation after each irrigation in summer; cultivation in December after first rain to retain moisture.
R. E. Hutchinson, Fowler.	Clay and sandy loams.	...do	Plow, harrow, and cultivate after each irrigation.
W. G. Uridge, Fresno	Rich gravelly loam	...do	Two plowings and four cultivations.
N. Mudgett, Raymond.	Black, sandy, and red granitic loams.	Underflow from hillside seepage.	Do.

Summary showing cultivation practice in connection with irrigation, etc.—Continued.

Name and localtty.	Soil.	Irrigation.	Cultivation.
CALIFORNIA—cont'd.			
Interior valleys and foothills—Continued.			
M. D. Atwater, Merced	Sandy loam	Citrus fruit and olives irrigated.	One plowing and frequent cultivations to keep loose surface.
Mr. Davis, Atwater	Sandy soil	All fruits irrigated	Cultivate and cross cultivate after each irrigation.
A. J. Hesse, Merced	Sandy plain	do	One plowing; three or four cultivations, one after each irrigation.
W. T. Kirkman, Merced	Sandy loam	do	Two plowings and four or five cultivations.
J. W. Violett, Ione	Black and red loams	When rainfall is short	Two plowings and two cultivations.
Paul Le Boyd, Elk Grove.	Shallow, gravelly loam.	All fruits irrigated	Plow once, cultivate twice, harrow three times, mash clods once before July and then stop cultivation.
C. E. Mack, Florin	Various loams	Citrus and small fruits, also olives and grapes on shallow soils.	For unirrigated land from three to six cultivations.
W. Johnston, Courtland	Sandy loam	Only when rainfall is short.	Two plowings; two cultivations; two harrowings.
E. A. Gammon, Courtland.	Deep sandy loam	do	Three plowings and five cultivations.
G. K. Swingle, Davisville.	Alluvial sandy loam	do	One plowing; two or four cultivations.
F. B. McKevitt, Vacaville.	Heavy and light loams.	No irrigation	One plowing and at least twelve cultivations.
E. R. Thurber, Vacaville.	Clay and sandy loams.	do	One plowing and continual cultivation until August 1.
G. W. Hinclay, Winters	Decomposed sandstone.	do	Plow once; more cultivation and clodmashing the better.
F. W. Willis, Colusa	Alluvial	Winter irrigation	Two plowings and about eight cultivations.
B. F. Walton, Yuba City	do	Citrus and small fruits only.	Two plowings; cultivation each month until August.
G. M. Gray, Chico	Clay and sandy loams.	No irrigation, but would be advantageous in dry years.	One plowing and two to six cultivations.
Fred Scharr, Red Bluff	Heavy loam	No irrigation	One plowing and cultivation to keep loose surface.
L. C. Nilsson, Bayles	Sandy, gravelly, and clay loams.	Irrigation for small fruits.	Cultivate twice a month, May to August.
W. E. Whitmore, Whitmore.	Heavy, red volcanic loam and light loams.	All fruits irrigated	Three to six plowings, and cultivation after irrigation.
Owen Dailey, Whitmore.	Red loam	do	Two to three cultivations.
W. B. Gester, Newcastle	Red granitic loam	do	Two or four plowings and two or ten cultivations.
E. B. Beecher, Auburn	Heavy slate loam	do	One plowing and four to six cultivations.
J. E. Barnes, Ione	Red upland loam	do	Two plowings and four to eight cultivations.
T. J. Wagoner, Penn Valley.	Black loam, sandy loam, and red hill soil.	Grapes and berries	Four to five workings, with shovel plow and cultivator.
Mountain valleys.			
J. H. Stewart, Alturas	Sandy loam	All fruits irrigated	Three cultivations.
W. Sharwood, Soulsbyville.	Granitic loam	do	Trees grown in irrigated clover.
J. M. Harris, Miami	Alluvial and hill loams.	Some apples irrigated, some not.	One or two plowings; harrow or cultivate as often as weeds grow.
L. E. Grove, Miami	Clay and sandy loams.	Small fruits irrigated	Two plowings and two summer cultivations.
F. Femmons, Gertrude	Granitic and sandy loams.	Slight irrigation just before ripening.	Winter and spring plowings; four to six summer cultivations.
Ross Lewers, Franktown, Nev.[a]	Black leaf mold and sand.	All fruits irrigated	Young trees with hoed crops; old trees in grass.
T. E. Jones, Bishop	Clay and sandy loams.	do	
N. C. Cooley, Bishop	Sandy loam	do	Seven or eight cultivations.
J. Baxter, Independence.	do	do	About three cultivations.

[a] This report is inserted here because it comes from a Nevada point and is related to those that follow in that part of California east of the Sierra Nevada Mountains.

Summary showing cultivation practice in connection with irrigation, etc.—Continued.

Name and locality.	Soil.	Irrigation.	Cultivation.
CALIFORNIA—cont'd.			
Mountain valleys—Continued.			
C. A. Walter, Independence.	Sandy and gravelly loams.	All fruits irrigated ...	One plowing; two cultivations.
W. Chappelow, Llano..	Sandy	.....do	One plowing; cultivation after each irrigation.
A. B. Eels, West Palmdale.	Granitic loams	Seepage underflow from adjacent mountains.	One plowing; two to three cultivations.
O. L. Livesay, Fairmont.	.....do	To start young trees..	Plow once, harrow twice, chisel-cultivator once, weed-cutter two to four times.
T. O. Bailey, Nellie.....	.....do	No irrigation	One plowing and two to three cultivations.
Chester Gunn, Julian..	Light and heavy loams.	.....do	One or two plowings and frequent cultivation until fall.
ARIZONA.			
James Page, Verde	Black clay loam and sandy or gravelly loams.	All fruits irrigated ...	
J. K. Hall, Agua Fria...	Rich alluvial	.....do	
C. T. Adams, Phoenix..	Light loams and heavy clay loams.	.....do	Fall and spring plowing, using cultivator and harrow for eight months after each irrigation.
O. Allen, Phoenix.....	Desert loam	.....do	Plow in winter; mow weeds several times in summer, leaving them on the ground.
G. H. Clayson, Phoenix	Sandy, gravelly, and clay loams.	.....do	Clean cultivation with eight or ten workings, but clean cultivation is killing the trees.
E. N. Wilson, Phoenix .	.....do	.....do	
C. Williams, Phoenix ..	Sandy	.....do	Hoe around trees constantly; clean culture of open spaces is being abandoned, as it wears out the soil.

GENERALIZATIONS FROM SUMMARY.

The foregoing account of actual practice of fruit growers throughout the whole area of the Pacific States affords opportunity for long study, but only a few deductions can be made at this time. It will serve as a guide to practice, and by comparisons of methods and frequency of cultivation it will yield many suggestions of practical value to the grower. A broad view of the prevailing practice justifies the following generalizations:

First. Clean summer tillage is almost a universal practice in the fruit regions of the Pacific coast. If space had permitted the introduction of reports from the more humid region of the coast, like those given above, it would have appeared that a few growers in regions of heaviest rainfall approve the growth of cover crops, like clover, after the trees reach bearing age, and also that others employ scant summer cultivation, or cultivation for a short period only. The idea of these growers is that such practices relieve the soil of excessive moisture, either by the growth of the cover crop or by facilitating surface evaporation, and so prevent the tree from being stimulated to too large wood growth, or maintaining growth so late in the season as to enter

the frost period in too active a condition and with new wood not properly matured. Quite in contrast with this is the practice, which is gaining ground in the hottest parts of the irrigated region, of growing alfalfa as a cover crop for the purpose of shading the soil and thus reducing soil temperature and, perhaps, of avoiding the ill effects of the reflection of burning sun heat from a smooth surface of light-colored soil, or the ill effect of "burning out of humus" by clean summer culture. In such cases more irrigation is needed to supply enough water for the growth of both trees and cover crop. But at present these exceptions are of rare occurrence.

Second. The adoption of a policy of clean cultivation in the dry season is not conditioned upon the amount of moisture available either by rainfall or irrigation. The table shows that it is pursued both where irrigation is practiced and where it is not, and also where the rainfall is greatest and where it is least. It prevails in the humid region where rainfall may rise to 60 inches or more and in the arid region where it may not exceed one-tenth as much. As a matter of fact, there does not appear to be a good fruit soil so deep and retentive that it can retain enough even of a very heavy rainfall to effect good tree growth and fruit bearing if it is forced to sustain the loss by evaporation from a compact surface during the long dry season following. There may be, it is true, soils weak in capillarity, in which water can not rise from a great depth and in which deep rooting plants may find ample water in the subsoil, providing it is held there by impervious underlying strata. There are many more instances where loss by natural drainage is added to loss by evaporation. But, disregarding exceptions, the loss of moisture by both drainage and evaporation during the dry season is so great that the soil to a depth of several feet loses practically all the water which is available for plant growth, and the trees fail or become unprofitable. Loss by drainage can not, practically, be prevented, but loss by evaporation can be so reduced that trees and vines will be adequately supplied in spite of the loss by drainage. Because, therefore, the soil can not retain enough water in its natural state, no matter how much it may receive, clean summer cultivation, involving quite complete and more or less frequent stirring of the surface to the depth of 4 to 6 inches, is the almost universal practice, irrespective of local rainfall or of irrigation.

Third. The prevailing motive, then, for cultivation in the dry-summer region is moisture retention. In this respect good surface tilth is so effective that, though enough moisture can not be retained without it, so much can be retained with it that, even where irrigation or rainfall is moderate in amount, it may serve all purposes of the tree or vine. Thus cultivation enters into the fruit-growers' practice in the region under consideration, not to make large rainfall effective, as it does in

some parts of the region, but to make moderate rainfall effective, or to make small irrigation effective, by increasing the duty of water which is applied. It becomes not only a ruling consideration in the effectiveness of a certain amount of rainfall, as has already been suggested in another connection, but it also determines the success of irrigation and the amount of water required; for, although it was an early and rude practice to rely upon irrigation to support uncultivated fruit trees and to irrigate more and more frequently as the ground became harder from its use, this policy has now no standing in commercial fruit growing. Not only was it wasteful of water, but it was otherwise detrimental to the thrift of trees.

Fourth. Thorough cultivation, both in winter and summer, has other very important ends in view. It opens the soil and promotes aeration; it encourages deeper rooting and thus encourages the tree to take possession of a greater soil mass both for moisture and other plant food. It is part of a very valuable policy of increasing humus by plowing under the natural growth of weeds or specially sown legumes. This increases the amount of organic matter in the soil, adds new plant food, promotes the friability of heavy soils and the retentiveness of light soils, and is otherwise valuable. Green manuring in some parts of the region is done by plowing in winter growths in the spring. In the localities where summer growth of alfalfa as a soil cover is advocated as a substitute for cultivation, cutting the crop without removing it, but allowing it to disintegrate in place, is held by some growers to be additional protection to the soil surface and some addition to its supply of plant food.

Fifth. The exact methods by which desirable conditions of tilth are to be secured are in part dependent upon the local soil and climate and in part upon the individual conceptions of growers. It will not be possible in this connection to undertake an elaborate analysis of the methods reported in the preceding table, nor their relations to attendant circumstances of rainfall, soil, and irrigation practice. It will appear, however, that very diligent cultivation is practiced both by those who rely upon local rainfall and by those who irrigate. Irrigators cultivate most frequently, which is not, however, evidence that their methods are better than those of nonirrigators. Frequency of irrigation is in itself not desirable if it can be avoided, as will be discussed in another connection. Frequency of cultivation with irrigation simply indicates that so often as the soil is thrown out of good condition for moisture retention, so often must such good condition be restored. If it should be concluded from the wide collection of data that the prevailing practice is in the line of more frequent working of the soil than some employ, the lesson would be a valuable one. There enters here, however, the proper study of the soil with which each grower has to deal, the behavior of his trees, and the quality of his fruit

under his present methods, and a reasonable amount of experience on his part to determine whether he has not something to learn from the example of the more diligent soil workers whose practice is outlined in the table.

Sixth. To one who has observed the evolution of culture methods on the Pacific coast for the last twenty-five years, the data included in the preceding table are particularly interesting as showing the increasing popularity of the plow in orchard and vineyard work. There was a time when on our lighter loams various styles of cultivators and harrows seemed likely to rule out the plow. Where rainfall is small these tools worked so well both winter and summer that it seemed a good and economical policy to keep the ground always clean of weeds and with a finely pulverized surface. Where the soil was more retentive and the rainfall heavier, the land was frequently out of condition for winter working, the weeds and native clovers grew freely, and the plow always seemed indispensable to cover in the green stuff and break up the compacted surface. At the present time, as the foregoing data show, the plow has regained its standing as the proper basis for satisfactory summer pulverization. This has come from the very wide observation that continued shallow work with the cultivator causes a hardpan at whatever depth the teeth cease their cutting, and this hardpan in many soils even of rather coarse nature may become so cemented that the penetration of moisture is arrested and the subsoil becomes too dry for the best root growth, although the surface layer may be frequently saturated by rain or irrigation. This condition is aggravated by irrigation, but may be corrected by better methods in the application of irrigation water, as will be shown in the proper connection later. A continuous rain may partially overcome it. The usefulness of the plow in deeper disintegration, in opening the soil to deep reception of water and in laying a foundation of good tilth by its deeper reach and by its superior breaking action, is now being widely recognized. There are now very few cases in which the plow is not used once in the year, and in many cases two plowings are held to be desirable. Deep plowing of a central strip between the rows and shallower plowing nearer the trees or vines is a common practice. The table shows that some growers make much freer use of the plow. It is probably true that in some parts of the coast the modern cultivators are not yet well known and their economy recognized. The turning of the soil in the dry season is accompanied by a loss of moisture, which is unnecessary and can be avoided by the newer implements which stir deeply and thoroughly without turning.

INTERCULTURE IN ORCHARD AND VINEYARD.

Closely related to cultivation is the practice of intercropping, and it is so important that special inquiry was made to ascertain the present practice and general attitude of the growers toward it. The first and most wide-reaching conclusion is that the policy of intercropping for any purpose whatever is not in favor with two-thirds of the growers. Out of 286 replies to questions on this subject received from all the districts of the coast, both in humid and arid sections, 187 declared against intercropping, while 99 favored it. In many cases, however, such favor was provisional and restricted. The matter is of such importance in connection with irrigation practice that the following table has been prepared to show the practice of growers who favor intercropping throughout the territory covered by this report:

Summary showing interculture in orchard and vineyard.

Name and locality.	Irrigation.	Intercropping.
IDAHO.		
H. A. Russell, Kendrick	Little or no irrigation.	Small navy beans; average, 1,000 pounds to the acre.
E. H. Libby, Lewiston	Irrigated	Berries and root crops until trees are 4 or 5 years old.
W. W. Wells, New Plymouth	do	Nothing, but others grow berries and root crops.
W. G. Whitney, Payette	do	Small fruits during first 3 or 4 years.
A. P. Hartley, Caldwell	do	Better nothing, but some grow corn 2 years.
Geo. Little, Caldwell	do	Berries and currants only.
Robt. Milliken, Boise	do	Hoed crops first 3 years.
A. McPherson, Boise	do	Corn and vegetables first 3 years.
W. A. Sample, Blackfoot	do	Potatoes and berries.
NEVADA.		
Ross Lewers, Franklin	Irrigated	Hoed crops for young trees; old trees in grass.
WASHINGTON.		
Fred Eichholtz, Edison	No irrigation	Small fruits in young orchard: after 8 years of age, red clover.
John. A. Stewart, Christopher	do	Vegetables and small fruits until 8 years old; then clover or grass.
J. H. Kinney, Mount Vernon	do	Potatoes, 5 or 6 years; after that, nothing.
C. Robinson, Chelan	do	Corn and potatoes, 3 years; after that, nothing.
L. H. Spader, Chelan	do	Corn, 20 to 40 bushels per acre.
J. W. Himes, Elma	do	Hoed crops until trees bear; nothing afterwards.
A. L. Aabling, Seattle	do	Vegetables, 4 to 5 feet each side of the trees.
A. M. Ferrell, Redmond	do	Vegetables, first 5 or 6 years; afterwards, field peas and red clover, alternate years.
H. C. Cook, White Salmon	do	Corn for first 8 years; afterwards, nothing.
F. A. English, Farmington	do	Vegetables until trees come into bearing.
Geo. Ruedy, Colfax	do	Any hoed crops while trees are young.
E. P. Gilbert, Spokane	do	Any hoed crops.
D. W. Bridgman, Latah	do	Beans, peas, squashes, melons, carrots, and potatoes.
Jason Whinney, Spokane	do	Vegetables or corn while trees are small.
F. E. Thompson, Parker	Irrigated	First 2 years, potatoes; afterwards, clover sod.
A. E. Koehler, Wenatchee	do	Corn and potatoes, 4 or 5 years.
J. N. James, Waitsburg	do	Berries and vegetables.
OREGON.		
Henry E. Dosch, Hillsdale	No irrigation	Cherries and pears, possibly apples, should be in sod when in full bearing.
A. Holaday, Scappoose	do	Corn, potatoes, and nursery stock, first 4 or 5 years.
J. S. Brooks, Lafayette	do	Potatoes, corn, etc., first 3 or 4 years.
H. Finley, Monroe	do	Potatoes, first 2 years.
L. T. Reynolds, Salem	do	Beans, corn, carrots, potatoes, etc., while trees are young.
Chas. L. Dailey, Salem	do	Nothing, except possibly vegetables. Some grow berries, but I don't approve it.
B. Cunningham, Liberty	do	Ground cultivated both ways for 4 years.
J. J. Harden, Stayton	do	Root crops and corn; only legumes to plow under.
C. E. Stewart, Medford	do	Crops until trees are 3 years old.

Summary showing interculture in orchard and vineyard—Continued.

Name and locality.	Irrigation.	Intercropping.
OREGON—continued.		
H. W. Oliver, Summerville	No irrigation	Corn, beans, and potatoes until trees shade too much.
S. A. Miller, Milton	Irrigated	Strawberries, first 3 years.
Thos. Spence, Milton	do	Crops until trees are 8 years old.
CALIFORNIA.		
Mrs. Victor Hope, Blocksburg.	No irrigation	Corn is grown among young trees.
W. H. Bailar, Fortuna	do	Strawberries, carrots, potatoes.
G. W. Brant, Fish Rock	do	Vegetables in summer; in winter grass to plow under
E. F. Cook, Napa	do	Root crops.
W. H. Hilton, Glenellen	do	Corn.
Robert Hall, Sonoma	do	We grow corn when starting young orchard.
B. H. Upham, Martinez	do	Corn for fodder while trees are young.
F. Barbour, Clayton	do	Corn in wet years to protect trees from grasshoppers.
E. M. Ehrhorn, San Jose	do	Pumpkins, carrots, and corn only when trees are young.
A. Block, Santa Clara	Irrigated	Peas and carrots for farm use only.
E. Berwick, Monterey	do	Berries, corn, potatoes, beans, squashes, and mangels.
R. W. Eaton, Watsonville	No irrigation	Corn, potatoes, and beans from 1 to 5 years.
J. A. McCune, Watsonville	do	Corn 2 years.
James Waters, Watsonville	do	Berries when trees are young; better nothing after 3 years.
J. A. Girard, Cayucos	do	Corn or hoed crops, but better nothing.
Fred Scharr, Redbluff	do	Sorghum while trees are young.
Wm. Johnston, Courtland	do	Watermelons, cantaloupes, squashes, etc.
Paul Le Boyd, Elkgrove	Irrigated	Corn fodder if trees are far apart.
J. W. Violett, Ione	No irrigation	Potatoes, pumpkins, and peas.
J. E. Barnes, Ione	Irrigated	Pumpkins and root crops when young.
A. J. Hesse, Merced	do	Vegetables; but danger of giving trees too much water.
Geo. C. Roeding, Fresno	do	Pumpkins until trees come into bearing.
W. G. Uridge, Fresno	do	Only low-growing vegetables in center of wide rows.
J. S. McCormick, Eaton	do	Pumpkins and watermelons while trees are small.
J. T. Bearss, Porterville	do	Sorghum while trees are young.
W. G. Gester, Newcastle	do	Small fruits for a year or two at most.
Nelson Mudgett, Raymond	Subirrigated	Watermelons.
J. H. Stewart, Alturas	Irrigated	Vegetables when trees are young; afterwards alfalfa.
W. E. Whitmore, Whitmore	do	Beans; usually red clover is desirable.
Owen Dailey, Whitmore	do	Vegetables first 3 or 4 years.
H. C. Fuchs, Grass Valley	do	Berries while trees are small.
Frank Femmons, Gertrude	do	Squashes and other vines while trees are young.
W. Sharwood, Soulsbyville	do	Clover and potatoes in rotation.
L. E. Grove, Miami	do	Only green crops to plow under.
John Baxter, Independence	do	Corn and all kinds of berries while trees are young.
N. C. Cooley, Bishop	do	Berries and currants.
Ellwood Cooper, Santa Barbara.	No irrigation	Beans are grown, but inadvisable.
J. V. Alvord, El Rio	Irrigated	Beans when trees are small; afterwards nothing.
H. J. Dennison, Nordhoff	No irrigation	Squashes to 2 or 3 years old.
A. S. Thatcher, Nordhoff	Irrigated	With enough water many things would pay.
Frank Dunn, Fillmore	do	Beans, but better with nothing.
O. E. Roberts, Colegrove	do	Tomatoes and beans during the winter.
L. T. Garnsey, San Fernando	do	Vegetables until trees are 4 years old.
F. E. Gray, Alhambra	do	Small fruits.
J. F. Branch, Artesia	Subirrigated	Beans or peanuts.
R. H. Howard, Riverside	Irrigated	Melons until trees are 4 years old.
James Boyd, Riverside	do	Pumpkins, etc., only when trees are small.
L. Yates, Elsinore	do	Vegetables in a small way.
Judson Williams, Fallbrook	do	Green manure plants only.
T. O. Bailey, Nellie	No irrigation	Corn, potatoes, cabbage, and turnips.
Jobes Brothers, Escondido	Irrigated	Beets, corn, etc., up to sixth year.
L. E. Kent, Poway	do	Potatoes, beans, etc.
G. P. Hall, San Diego	do	Strawberries sometimes profitable.
J. P. Jones, Linda Vista	do	Vegetables and strawberries in some cases.
ARIZONA.		
James Page, Verde Valley	Irrigated	Corn.
Orlando Allen, Phoenix	do	Grow clover for hay.
G. H. Clayson, Phoenix	do	Alfalfa mowed and left on the ground.
W. Wilson, Phoenix	do	Strawberries do fairly well.
Chas. Williams, Phoenix	do	Beans and potatoes.
J. H. Bowman, Tucson	do	Beans among young trees with profit.

The practice of intercropping, either for the direct value of the crop, or for the indirect advantage of it as a green manure, or for a ground cover, is conditioned upon the amount of water available, either by irrigation or rainfall, and upon the character of the soil.

Where the soil is deep and retentive, and the rainfall large, intercrops may be admissible, so far as moisture is concerned, because there may be enough present for both the trees or vines and the intercrop, but they may be undesirable because of exhaustion of fertility which should be conserved for the later use of the fruit plants. It is a prerequisite, therefore, to intercropping that the soil have not only surplus moisture but surplus fertility which can perhaps be drawn upon for present use and restored later as it may be needed. Unless such surpluses are available, the whole tenancy of the ground should be awarded to the trees and vines, unless intercropping be resorted to for the purposes of using abundant moisture in the growth of legumes which may be plowed in for the future benefit of the main crop. But there are locations where great depth and fertility and ample rainfall coincide, and in a few such places orchard trees are still vigorous and profitable, although for twenty years or more intercrops of small fruits and field vegetables have been continuously grown.

Intercropping with irrigation is subject to the same conditions in respect to ample water supply. When water is available it can be applied as needed and long retention in the soil is not essential, as is the case with rainfall. For this reason intercrops are more popular in irrigated regions than elsewhere and can be undertaken on shallower and less retentive soils. The question of fertility is, however, also important, but most of the soils of the arid region which are chosen for fruit are very rich. Because they have not been leached by excessive rainfall they retain relatively larger supplies of plant food than the soils of the humid region, and the planter is often much aided in the problem of maintenance while his fruit trees are coming to bearing age by turning a part of the strength of his soil into saleable produce.

The resort to cover crops as a substitute for clean cultivation is coming into greater prominence in irrigated districts. In western Oregon and Washington, where rainfall is very heavy, the growing of clover in old orchards has been long practiced, as has already been stated in another connection. The use of cover crops to protect the soil in the hotter irrigated regions has also been mentioned and its claims to advantage stated. The foregoing table gives data on these points. The practices are commendable under the conditions cited in each case and are likely to increase in popularity. The cover crop should be a legume if possible, and owing to degrees of hardiness different plants may be chosen for summer and winter growth. There are objections to perennial legumes, because their use prevents culti-

vation and aeration of the soil, and because the undisturbed soil favors the increase of injurious insects and rodents. These dangers are, however, reduced by having irrigation arrangements by which the water may be held upon the ground for a length of time in winter. A newer practice is the use of legumes, like peas, lupines, melilot, etc., which grow during the winters, in the southern parts of the coast region at least, to be plowed under in spring, and, after this plowing, sowing summer legumes, like cowpeas, crimson clover, etc., to be turned under in the fall. This practice is rather expensive in seed, work, and water, perhaps, but where water is abundant and cheap, it is questionable whether the salutary effects of soil protection and the value of the plant food added to the soil can be secured so cheaply in any other way. At present, as shown in the table, some growers cling to the free use of water and the growth of alfalfa as a good practice in hot, dry regions.

The table gives a long list of plants as commended for growth among fruit trees. So great is the variety that no clear deductions can be made as to the nature of the plants to be chosen. It seems to depend largely upon the use or market which the grower has for them. Obviously, however, it should be a plant which admits of good summer cultivation, unless the land is to be laid down in clover and water freely used. In most cases the crop must be grown in rows or hills, and the soil be frequently and thoroughly worked to prevent evaporation. Where full cultivation is not provided for, the leafy vines of the squash family are thought to be serviceable in soil shading, and this class of plants is particularly popular in the California irrigated districts.

IRRIGATION SEASON AND FREQUENCY OF APPLICATION AND AMOUNTS OF WATER USED.

After conservation by cultivation and other schemes devised for the economical use of water, the next question is as to the irrigating season, the frequency of application desirable, and the amounts of water actually used. Along these lines very careful inquiry has been made to ascertain the views and practices of growers, and tabulations of results will be given below. That growers are seriously in error as to the amounts of water they use; that they often use more than they think; that they sometimes use more than they need, and that they do not always secure the highest duty of which the water is capable are all strong probabilities. The demonstration must come from more comprehensive and accurate studies than have yet been made, although the publication of such data as are now available affords opportunity to study the question from accurate measurement of water and crops produced.[a] The further pursuit of the study will yield results of incalculable value. It is still, however, important to have the wide collation of growers' con-

[a] U. S. Dept. Agr., Office of Experiment Stations Buls. 86 and 104.

ceptions of amounts of water used, which this special inquiry yields. Comparison of these with the results of measurement will be an interesting effort of the future.

In preparing the following table most careful effort has been made to fairly translate the various estimates which individual growers submitted to a uniform standard of acre-inches. The results both in estimate and calculations are as accurate as effort and inquiry, sometimes several times repeated, can make them:

Summary showing irrigation season and frequency of application and amounts of water used for deciduous fruits on the Pacific coast.

Region.	Rain-fall	Irrigation season.	Number of irrigations.	Depth of each irrigation.	Total depth for season.
IDAHO.	*Inches.*			*Inches.*	*Inches.*
Lewiston Valley	14–20	July to Sept. 15	3–5	1.5–2	4.5–10
Weiser Valley	....	May to August	4	12	48
Do	....	.....do	3–4	3	9–12
Payette Valley	....	May to Aug. 15	3–5	....	36
Do	....	....	4	....	14–24
Boise Valley	....	May to August	4	3	12
Do	8–12	April to August	4–6	....	....
Do	....	May to August	3–6	....	30
WASHINGTON.					
North Yakima	....	June to September	2–4	2	4–8
Parker	3–6	June to August	4	2	8
Wenatchee	....	June to August and in October.	2–6	....	24
Lincoln	....	June to August	....	....	5.5
Touchet	17	.....do	3	....	....
CALIFORNIA (COUNTIES).					
Shasta	45	June to August	11	1.5	17.5
Do	40	.....do	3–4	2	8
Butte	....	May to July	2–3	6	12–18
Butte	28	February	1	12	12
Colusa	12	Winter	1 or 2	12	12–24
Nevada	40	Summer	1	2.5	2.5
Placer	25–35	June to October	12	1	12
Do	25–35	May to October	10	2	22
Do	25–35	May to September	10	1.25	12.5
Sacramento	20	June to September	18	1	18
Do	18	June to October	5	1	5
Do	18	July to September	3–4	1.25	3.25–5
Do	18	June to August	8–10	1.25	10–12.5
Santa Clara	20	March and May	2	6–8	12–16
Do	20	February and May	2	6	12
Do	20	March to June	1–3	3–12	9–12
Do	20	Summer	2	3–4	6–8
Do	16	March to June	1–3	3	3–9
Do	20	March	1	12	12
Do	15	July to August	3	4	12
Do	12	Winter	1	8–10	8–10
Do	20	January to July	3	4	12
Monterey	13	February to June	1–4	4	4–16
Merced	12	Summer	3–4	2–3	6–12
Do	10	.....do	2–4	3–6	12–24
Fresno	8	.....do	3–4	2.5	7.5–10
Do	8	February	1	12	12
Do	8	March to July	2	6	12
Kings	7	Summer	2–4	4	8–16
Tulare	....	March to May	1	6	6
Kern	4	March to June	2	4	8
Inyo	3.5	April to August	5	1.5	7.5
Santa Barbara	....	March and May	2	1.5	3
Los Angeles	18	March or April	1	6–9	6–9
Do	20	July	1	6	6
Do	12	June to November	2–3	2	4–6
Do	....	June to October	3	2.75	8.25
Orange	15	March or April	1	12	12
Do	12	Summer	2–3	2	4–6
Do	....	.....do	2	4	8
Do	....	January, March, June	3	4	12
Do	....	Winter	1 or 2	4	4–8
Do	....	Summer	2	3	6
Do	....	.....do	2 or 3	4	8–12

Summary showing irrigation season, etc.—Continued.

Region.	Rain-fall.	Irrigation season.	Number of irriga-tions.	Depth of each irri-gation.	Total depth for season.
CALIFORNIA (COUNTIES)—cont'd.	*Inches.*			*Inches.*	*Inches.*
San Bernardino		Summer	1	6	6
Do		....do	2–3	6	12–18
Do		April to October	3–5	2	6–10
Riverside		March to August	3–4	2	6–8
Do	15	May to September	3–6	1.5	4.5–9
Do		March to October	6–8	1.5	9–12
Do	10	April to September	3–4	1.66	5–6.66
San Diego		June to September	4	3–4	12–16
Do	8	Summer	3–5	2	6–10
Do	18	....do	3	3	9
ARIZONA.					
Verde Valley	11.44	March to September	24		([a])
Lower Lynx Creek	17	March to July; also winter.	Irregular.		([b])
Salt River Valley	7	Winter and spring	7 or 8		([c])
Do	7.5	March to December	10		6–12
Do	9.5	January to June	6		([a])
Do	7.5	All the year	Weekly.		([a])
Yuma	2–3	Twice in winter, monthly rest of year.	10		([a])

[a] Thorough soaking. [b] Use all water that can be caught in flood reservoirs on a foothill ranch. [c] Undetermined.

Summary showing irrigation season and frequency of application and amounts of water used for citrus fruits in California.

County.	Rain-fall.	Irrigation season.	Number of irriga-tions.	Depth of each ap-plication.	Total depth for season.
				Inches.	*Inches.*
Butte		April to October	5–6	4.5	22–26
Fresno	8	....do	2–7	2	4–14
Tulare		March to September	6	2	12
Do	10	April to October	5–8	4	20–32
Do		March to October	8–10	6	48–60
Santa Barbara		....do	5–7	2	10–14
Ventura	20	....do	5–6	2.5	12.5–15
Los Angeles	12	June to October	3	6–9	18–27
Do	10	May to October	6	3.5	21
Do	18	June to October	3	4	12
Do	20	July to September	3–4	1.5	4.5–6
Do	20	....do	3–7	1	3–7
Do	20	....do	6	0.75–2	4.5–12
Do	20	March to November	7	1.5	10.5
Do	18	....do	3	2	6
Do	15	May to October	6	1.5	9
Do	18	July to October	4	1.5	6
Do	18	April to October	7	2.5	17.5
Do	18	May to October	6	2.75	16.5
Orange	18	May, July, September.	3	4	12
Do	15	May to October	4	2.5	10
Do	10	....do	4–8	2	8–16
Do	12	....do	6–8	4	24–32
Do	12	When needed	8	5	40
Do	12	March to December	3–5	4	12–20
Do	12	When needed	8	2	16
San Bernardino		March to October	8	.75–1.5	6–12
Do	12	June to October	6–7	4.5	24–31.5
Do	12	May to September	4–6	6	24–36
Do	12	April to December	8	2	16
Riverside		When needed	8	2	16
Do		....do	9	1.5	13.5
Do	12	May to November	7	3	21
Do	7	April to September	6	1.66	10
Do	10	April to November	7	3	21
Do	8	April to December	8		
Do	11	May to November	3–7		
Do	10	May to September	4–6	6	24–36
San Diego	8	May to October	4	2.5	10
Do	12	....do	5	3	15
Do	10	....do	4–8	2	8–16
Do	8	....do	6–8	4	24–32
Do	18	June to October	3	3	9

Obviously in irrigation practice the season at which water is applied and its frequency and amount are all conditioned upon local rainfall, topography and soil, atmospheric conditions, and the requirements of the plants grown. These same conditions are factors in determining whether irrigation is in any case desirable at all, and they have been already quite fully discussed (p. 10). As these factors are extremely variable within the same geographical area, it is not possible to secure trustworthy results from close analysis of the insufficient data presented in the tables, nor are generalizations safe. The tabulations do, however, bear out very strongly the conclusions previously arrived at concerning the sufficiency or insufficiency of rainfall (p. 17), and also that one must study logically all natural conditions in earth, air, and plant in determining need of irrigation. The same is obviously true also of the present data, which represent but attempts on the part of many growers to measure that need. There are also to be found in the tables pertinent suggestions of the ways in which water is used, which each one interested can study from his own point of view.

In the first place, the table gives more definite form to the distinction drawn between regions partially or occasionally irrigated and those regularly irrigated (p. 9). Where one or two irrigations only are mentioned for the summer, the rainfall usually needs only a small addition of irrigation water to supply the full moisture needs of the crop. The depth of water applied for the season varies with different growers and in different regions, according to local conditions. The extremes for total depth are 2.5 inches and 60 inches. The larger amounts are used in the lighter, deeper soils and in the regions of greatest heat and least rainfall. Where a single irrigation is specified as being given in the winter, it is to directly supplement the rainfall by adding more water during the rainy season, the object being to carry the trees through the summer without irrigation by means of thorough and clean cultivation for moisture conservation. It is interesting to note that those practicing winter irrigation, although widely separated geographically, endeavor to apply a depth of about 1 foot of water, although there are others who use less. There would naturally be differences as to the amounts the different soils would absorb, but there are also differences in the supplies available in the winter in different districts. Where water is most abundant and costs least, it is most freely used. There is good reason to doubt that a foot of water at one application is actually desirable or that there are soils which can retain it within reach of tree roots.

Where the number of irrigations is more than three, it may be taken as indicating that irrigation is considered essential to the satisfactory growth of even deciduous fruits, and that regular irrigation is the policy of the growers. This, too, is supplementary to rainfall, but,

owing to local conditions of soil and climate, the rainfall, no matter how large it may be, can not be relied upon to carry the trees through the dry season. The fact is that the soil is not capable either of receiving the heavy rainfall or of long retaining such portions as actually enter it. There is, then, a considerable part of the rainfall which is worse than worthless, because it does injury by soil washing and soil leaching, and places where extremely heavy rainfall occurs may be actually worse off than other places with less rainfall. The table clearly shows that some localities of large rainfall also lead in amounts of water supplied by irrigation. The converse is also true, for some localities of light rainfall report success with deciduous fruit trees with a minimum amount of irrigation water. Without making too much of individual reports, because of the chance of error in the conceptions of correspondents, which has already been freely admitted, there appear instances enough to warrant the conclusion that the deciduous fruit tree can winter successfully with a small moisture supply, and is, in fact, in less danger from lack than from oversupply at this time of the year. If there be enough moisture to prevent injury from evaporation, either during high temperatures at the South or during low temperatures at the North, the tree will start good growth as the season advances and continue it if irrigation is given promptly and in sufficient quantity. There must always be a determination of what is an adequate supply by reference to local conditions, but as an estimate of necessary rainfall has been made at 20 inches, it is evident that adequate irrigation may be very much less than that. The rainfall of 20 inches is distributed through six or seven months. Some of it consists of light rains, with long, dry intervals, where there is slight penetration and quick evaporation. Some of it is lost by run off and by drainage. It is not surprising, then, that some growers, having deep valley loams to render their irrigation effective, report success with deciduous trees with 8 or 10 inches of water applied just at the time of the tree's greatest needs and used, no doubt, with maximum efficiency. It seems to be a warranted deduction, from all data known to the writer, that 10 inches of water, applied at the right time to soils of good depth and fair retentiveness, and accompanied by good tillage for conservation, is an adequate supply for five months of growth and fruiting even when the rainfall is only about enough to prevent drying out or freezing out during the winter season. Some growers report use of less than this. Certainly less will do for young trees under favorable conditions, and some of the least amounts are reported from the newly planted regions. As the trees advance in age and bearing, larger amounts will be required. The instances of greatest frequency of application may be taken as indicating soils lacking retentiveness, either through shallowness or coarseness, or either of these accompanied by extreme summer heat

and aridity. So marked are these local conditions that while monthly use of water is, as a rule, satisfactory throughout the territory included in this report, there are places where water is used twice as often, and in others almost weekly applications are held to be necessary. There is good reason to think, however, that although local conditions may sometimes make such frequency necessary, practice should tend toward less frequency and greater penetration where this is possible.

The last table is an interesting showing of irrigation practice with citrus fruits in California. As these trees are evergreens, and as their habit is to make their chief fruit growth in the autumn after the work of the deciduous tree has been finished for the season, the irrigation season is for them much longer. As they are, in fact, almost always active and sustaining uninterrupted evaporation from their leaf surfaces, they must always be provided with moisture or ill will result to tree or fruit. They thus require more water than do deciduous trees. There is the same relation between irrigation and rainfall with citrus as with deciduous fruit trees, but the degree of relation is different. Many trials have shown that it is practically impossible to grow satisfactory citrus fruits without irrigation. There is no combination of heavy rainfall, or winter irrigation, and soil retentiveness which will supply the summer and autumn thirst of the orange or lemon in California. Irrigation, too, must be maintained both summer and winter wherever the rainfall is not well distributed and adequate. In the chief citrus regions of the State rainfall is seldom adequate except during January and February, and not always then. Under such conditions an estimate of the average requirements of citrus fruit trees in bearing would be about 20 inches of irrigation, irrespective of rainfall, although, as the table shows, there are localities of larger rainfall and more retentive soils where crops of these fruits can be made with 10 inches used just at the right time.

There are many other considerations involved in the requirements of different fruit trees at different ages and at different seasons of the year, which have been discussed in a previous bulletin,[a] to which the reader is again referred. The superiority of fruit grown with adequate moisture and the danger of excessive irrigation are also considered in that publication. It should be added, however, that the experience of the Pacific coast clearly shows that in order to secure fruit of high quality and marketable size there must be followed the faithful pursuit of approved horticultural methods in connection with adequate moisture. Regular pruning to promote the growth of strong bearing wood and to regulate the amount of it, so that the tree shall not undertake too great a task for its capacity; regular thinning of fruit to prevent its clustering on the bearing twigs, so that satisfactory size

[a] U. S. Dept. Agr., Farmers' Bul. 116.

can not be attained, and regular fertilization when the tree shows that the strength of the soil is decreasing, are all arts correlated with irrigation and must be intelligently pursued.

METHODS OF APPLYING IRRIGATION WATER.

In the Farmers' Bulletin above referred to (No. 116) a general discussion is given of irrigation methods and their relation to soil, topography, available water supply, etc. In this bulletin an effort will be made to present more fully the details of prevailing practices as ascertained by special inquiry.

The inquiry shows that flooding—that is, the free flow of water over the whole surface, or the flow between rows with furrows near the trees to retain the water in the interspaces—is only employed on some flat lands where winter irrigation is used to supplement rainfall when the latter is occasionally below normal. In such cases water is available in large quantities, and the lay of the land favors quite even distribution. Even under these conditions the experience of growers soon leads to the adoption of deep furrows or lateral ditches, or some simple check system, as superior to flooding. Summer flooding is done only by those who are unacquainted with better methods or who count their trees of too little account to warrant extra effort. It seems, therefore, a fair conclusion that flooding is only resorted to as a temporary expedient and has little standing.

THE CHECK SYSTEM.

With soils of such character that vertical percolation is very rapid, flooding in checks, by which water is held upon a particular area until it sinks below the surface, is considered necessary. There is a tendency to change from this method to a furrow system wherever practicable, because the former requires more soil shifting, a larger head of water for economical operation, more labor to handle it, more working in water and mud, and more difficult cultivation to relevel the land and to reduce a puddled surface to satisfactory tilth. For these and other reasons, perhaps, on loams of medium fineness one may find two adjacent growers pursuing different methods, while on coarse, porous loams the check system prevails, and on fine, retentive loams the furrow system is without a rival.

The check system can be seen on the most extensive scale in the upper part of the San Joaquin Valley, where the land is so level and the water so abundant that the checks can be measured by acres or fractions of acres.[a] In its most perfect form it is found in Orange County and some parts of Los Angeles County, where the checks are measured by feet, rarely by rods. Very large checks are chiefly used for field crops, although also employed for winter irrigation of vine-

[a] Rpt. on Irrigation, Senate Ex. Doc. 41, 52d Cong., 1st session, Part I, p. 307.

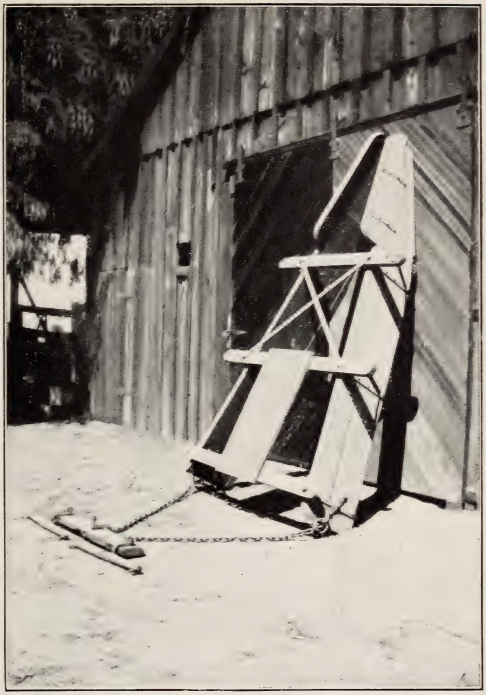


FIG. 1.—THE "RIDGER" FOR LEVEE MAKING IN THE CHECK SYSTEM.

FIG. 2.—THE V-SHAPED "CROWDER" AND METAL DAMS OR "TAPPOONS."

yards and orchards of deciduous fruits. With fruits, however, even in the same district, the tendency is toward using smaller checks carefully leveled before planting. With the large-check system permanent levees, either in rectangular form or on the contour plan, are generally used. The small-check system is chiefly laid off with temporary levees, quickly made with special appliances and as quickly worked back to a level as soon as the ground dries sufficiently after irrigation, and the whole surface kept well cultivated until the time arrives for a restoration of the levees for the next irrigation. The latter is the leading horticultural mode. It is carefully described by Mr. Sydmer Ross, of Fullerton, Orange County, Cal., as follows:

The check system, as carried out in the best-handled orchards, entails much hard work, but after you are through with an irrigation you know that each and every tree has had its full supply of water or you know the reason why. The ground must be cultivated, say, about 5 inches deep, so as to have plenty of loose soil with which to throw up a high ridge. Then a four or six horse "ridger" (Pl. II, fig. 1) should be run once each way between the rows, if it is a citrus or deciduous orchard, or twice should the trees be walnuts, because these trees are grown about 40 feet apart. After this is done the ridger should be run entirely around the outside of the piece to be irrigated, so as to have as perfect a ridge as possible on the outside. One man will ridge about 15 acres in a day. The ridger should be built with a steel plate extending along the bottom of both sides, bolted to the inside and projecting about 2 inches, so as to take good hold of the ground. Then with one horse attached to what is locally known as a "jump scraper," one side of the checks should be closed up, for the ridger in making the cross ridges breaks down the first ridge at its intersection. These repairs were at first made with a shovel, but the jump scraper, also called locally the "horse shovel," closes up the gaps very quickly. The practice generally followed is to close up the high side of the checks if the land does not cut by running water, but if it cuts, close up the lower side. (Pl. VII, fig. 2.)

After closing up the checks the ditches are plowed out and then the V-shaped "crowder" is run twice through them. (Pl. II, fig. 2.) On lands inclined to cut it is advisable that the length of the rows to be irrigated should not be over 250 feet, but in heavy land this distance can be considerably increased, if necessary, without danger of cutting the ridges by too long a run of water.

If the checks have been closed up on the low side of the ridge, it is better to run the water to the ends of the ditch and water the last row first; but if the high side has been closed up, it is best to water first the row nearest the gate or the main ditch, as the case may be, as in each instance dry earth will thus be available, if necessary, to close up the checks. The water is run down the row to the end tree, and as soon as the last check is filled it is closed up, and so on till all are filled and closed, when the water is turned down the next row.

To do good work it is usual to allow three men for every 50 inches of water, but in our own practice we have had much better results by dividing up our water and running from 35 to 40 inches to a ditch and allowing two men for such streams. In doing this we get better work and find it much easier for the men. If everything is well in hand, each man will irrigate about 30 acres in a day.

For turning the water from the ditches into the checks metal dams or tappoons are used. Pl. II, fig. 2, shows two of these, one of which has a gate for the division of the water when the stream is too large and is divided and two rows are watered at the same time. The gate is not a great success, as the water is apt soon to cut its way under the tappoon, but it may be much improved by having a shelf for

the water to drop on after it passes through the opening. The common practice for dividing water is to throw a tappoon partly across the ditch, putting a gunny sack on the opposite side to prevent cutting by the water. This is, on the whole, fully as satisfactory as using the tappoon with a gate.

All who follow this system should get ready for the water before it comes. A great many seem to think that if they ridge up their land; close up the checks, and plow out their ditches everything necessary has been done. Such is not the case, as ditches that are liable to cut should be fixed in the weak places with brush or burlaps. Old gunny sacks cut open and spread out are excellent for this purpose. Occasionally there are places where it is impossible to get a perfect ridge. These should be looked up and fixed with the shovel. The jump scraper will not entirely close up a check; it generally requires a shovelful or two to complete it. It is usual after the water is turned down one row to fix up the next one, but it is an excellent plan to have a few rows fixed up ahead, for there come times when breaks occur and there is not time to make the necessary repairs, and when water once gets the start there is apt to be much trouble and hard work before it can be put under control, besides doing poor work.

After the ground is dry enough to work, the ridges are split with a listing plow or a furrower attached to a cultivator. Then the ground should be run over with a harrow, setting the teeth to go well in, so as to pulverize the surface thoroughly. By using the harrow the ground can be worked about one day earlier than with the cultivator, and it also prevents the ground from baking till such time as it can be worked with the latter implement, besides doing far better work than with the cultivator alone, especially when there is much land to go over, as some of it is certain to get too dry before it can be reached, and then it will not pulverize well. All trees should be worked around by hand with either a fork or hoe as soon after irrigation as the ground becomes dry enough and before it becomes hard.

SPECIFICATIONS FOR HOMEMADE IMPLEMENTS FOR THE CHECK SYSTEM.

The following implements, used in preparing the ground for irrigation by the check system, were made on the fruit ranch of J. B. Neff, Anaheim, Cal., with the tools ordinarily found on a ranch and with but little help from the blacksmith:

The ridger.—This has sides of 2 by 16 inch pine 7 feet long, standing 18 inches apart at the rear and 5 feet apart at the front end. The sides may be made of two 2 by 8 inch pieces with 2 by 3 inch battens bolted on securely. The front crossbar is of 2 by 4 inch pine 6 feet 2 inches long and is set 20 inches from the end. The rear crossbar is of 2 by 4 inch pine 4 feet 4 inches long. It is set 7 inches from the end of the sides. The diagonal braces are 1 by 3 inch pine 6 feet 10 inches long. The short side braces are 2 by 3 inch pine 15 inches long. The lower inside edge should be protected by a strip of steel or iron $\frac{1}{2}$ by 2 inches extending to and around the front ends, which should be beveled to a sharp edge. The inside should also be lined with sheet iron 6 or 8 inches above the $\frac{1}{2}$ by 2 inch piece, and should have sheet iron pieces extending 16 inches beyond the rear end of the sides, tapered and braced in the manner shown in the cut for the purpose of making the ridger firmer at the top. Every part of the ridger should be firmly bolted with $\frac{3}{8}$-inch bolts, except the $\frac{1}{2}$ by 2 inch iron,

CHECK SYSTEM IN WALNUT ORCHARD IN MAY, IN ORANGE COUNTY, CAL. SCENE ON KATELLA RANCH.

CHECK SYSTEM IN WALNUT ORCHARD IN WINTER, IN ORANGE COUNTY, CAL. USE OF TAPPOON IN DIVERTING WATER FROM DITCH.

which should have $\frac{3}{16}$-inch bolts, and the sheet iron, which may be put on with nails. The hooks on sides for hitching draft chain are $\frac{3}{8}$ by $1\frac{1}{2}$ inches, and the draft chain is $\frac{3}{8}$-inch cable chain. (Fig. 1; Pl. II, fig. 1; Pl. V, fig. 2.)

The V-shaped crowder or ditcher.—This has sides of 2 by 12 inch pine and cross brace of 2 by 9 inch pine. The long side is 7 feet 8 inches long and short side 3 feet 6 inches long. This is also protected

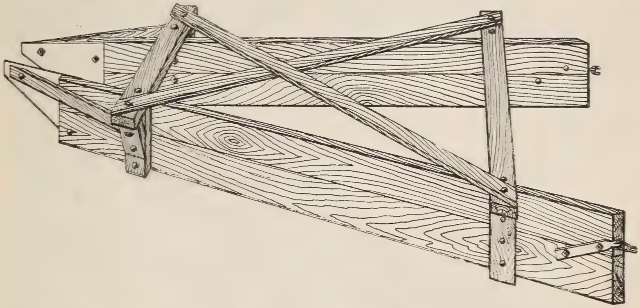


FIG. 1.—"Ridger" for levee making in the check system of irrigating trees and vines.

by a piece of steel or iron extending entirely around the ditcher and bolted with $\frac{3}{16}$-inch bolts. The sides come together in a point and stand at an angle of 45 degrees. The brace is placed 2 feet 10 inches from the point on short side and 3 feet 10 inches from the point on long side. It also has two handles, as shown in cut, 3 feet long. These are made of 2 by 3 inch pine reduced so as to hold conveniently. The sloping

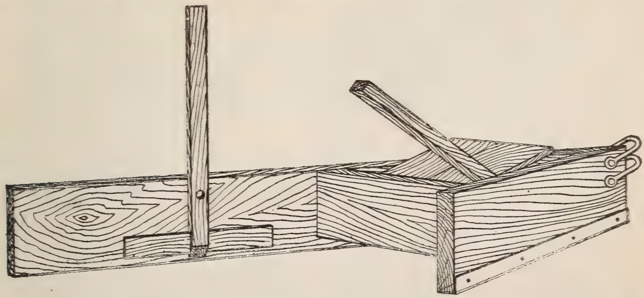


FIG. 2.—"Crowder" used in the preparation for distribution of water in the check system.

handle is bolted to the short side. When in use this implement stands with the short side elevated at an angle of about 35 degrees, and a floor is placed in the triangular space so that it will be level when in use. An ordinary wide clevis is used for the draft and is placed as shown in the cut. A vertical hole may be made in front of the clevis pin and a small rod driven in to strengthen the hold of the clevis. (Fig. 2; Pl. II, fig. 2.)

The jump scraper or horse shovel.—This is used for filling gaps in the ridges and is the work of the blacksmith. The beams are $\frac{1}{4}$ by $1\frac{1}{4}$

inches and 30 inches long from draft ring to the bend downward. The shovel is of No. 16 sheet iron 24 inches long by 18 inches deep. The handles are those used on any cultivator. The beams are bent to stand 6 inches forward of a square placed on top of the beams. The braces are of $\frac{3}{8}$-inch round iron. The shovel is slightly cupped to make it hold more earth. (Fig. 3.)

The portable gate or tappoon.—These are for shutting ditches, and are made of No. 16 sheet iron 2 feet wide and of any desired length, but usually 3 feet, 4 feet, or 5 feet long. The corners are cut off to a circle starting about 1 foot back of the corner. The handles are made of two pieces of 1 by 3 inch pine 12 inches longer than the gate,

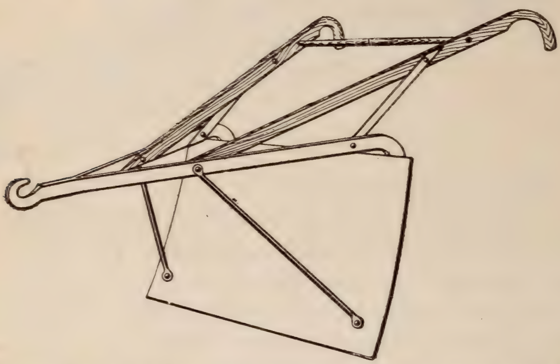


FIG. 3.—"Jump scraper" used to complete levees made by the "ridger" for the check system.

and are placed one on each side of the sheet iron and secured by $\frac{1}{4}$-inch bolts. (Pl. II, fig. 2.)

DOUBLE CHECKING, BASINING, ETC.

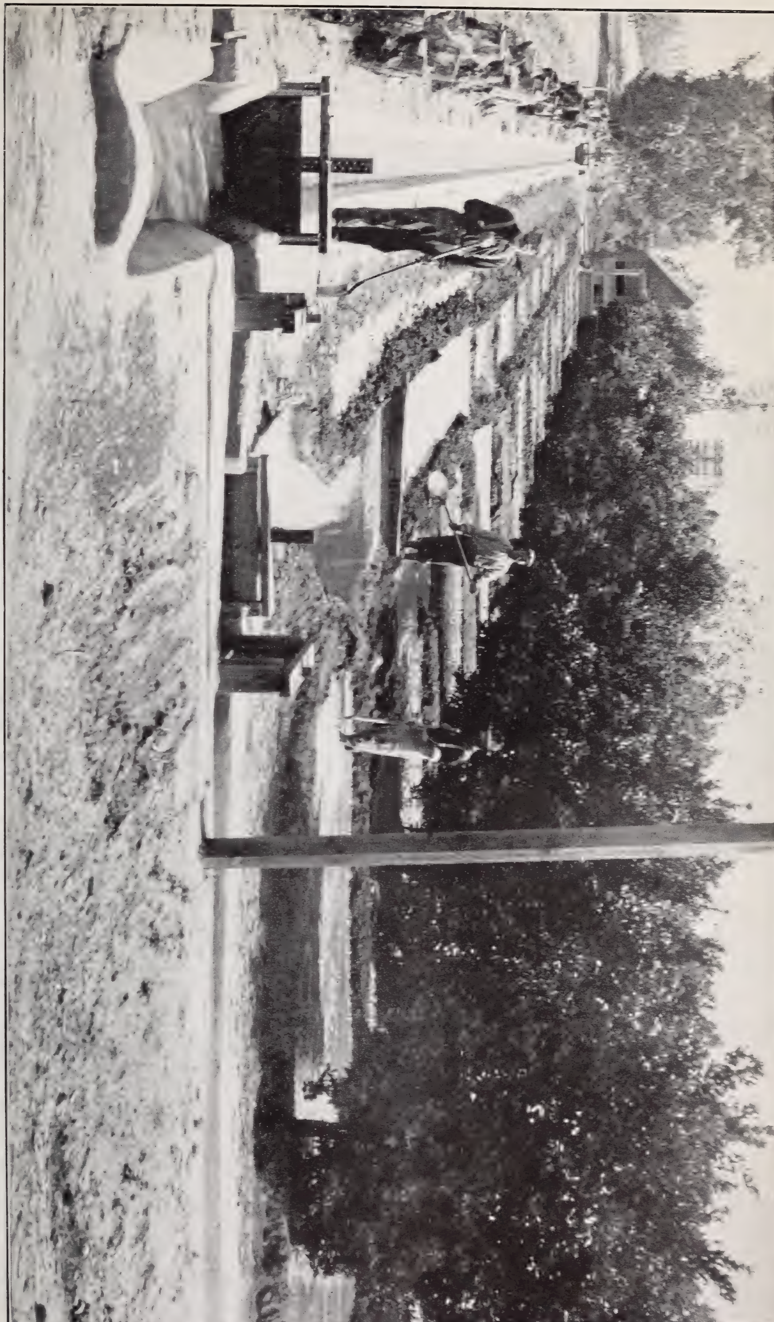
Double checking, where the rapid slope demands small inclosures, and basining, by which water is inclosed in small places near the trees and not spread upon the whole area, are both sufficiently described in Farmers' Bulletin No. 116, and their adaptations to exceptional conditions of soil topography and water supply are there indicated.

THE COMBINED CHECK AND FURROW METHOD.

An effort to escape in some measure the puddling of the surface which results from allowing water to sink away upon finely pulverized soil lies in the direction of breaking up the soil roughly in the bottoms of the checks, which facilitates the quick passage of the water into the subsoil. This is done by running a small plow or three large cultivator teeth attached to a single frame before the ridger is used to form the levees. Mr. A. D. Bishop, of Orange County, Cal., uses a

FIG. 1.—FURROWER AT WORK IN ORANGE ORCHARD OF A. D. BISHOP.

FIG. 2.—USE OF HOMEMADE RIDGER, ORANGE ORCHARD OF A. D. BISHOP, ORANGE COUNTY, CAL.



CEMENT DITCHES WITH DIVISION GATES, CHECK SYSTEM IN ORANGE ORCHARD OF MR. SYDMER ROSS.

combined furrow and check system as shown in the accompanying diagram (fig. 4.) He furrows the land first with a three-tooth furrower (Pl. V, fig. 1) at right angles to the direction in which the water is to flow and then uses the ridger (Pl. V, fig. 2) to make levees in line with the water, laying out the work so as to get the closest approximation to a level. When the levees are made, the jump scraper is used and the end of each third or fourth furrow bank is connected with the levees at alternating sides of the check made by the levees. This causes the water to flow through the furrows from side to side and distribute itself evenly over the whole ground. The number of furrows which can be passed before connecting with the bank depends upon the slope of the land—the nearer level the land the greater the

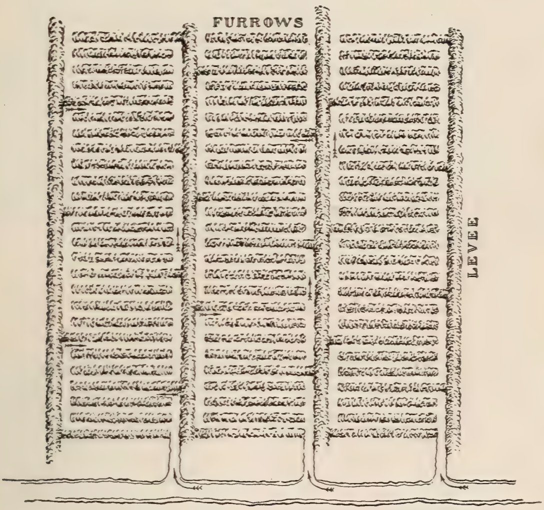


FIG. 4.—Combined check and furrow irrigation.

distance that can be left between the connections and vice versa. In this way the water is taken slowly down a grade where it would flow too rapidly were it admitted to furrows in the direction of its flow.

Another combination of the check and furrow system is found where the lowest spaces of a slope irrigated by furrows are laid off in checks to catch the overflow from the furrows and compel its percolation at a point which would otherwise receive too little water. The parts of a furrow system which lie farthest from the source of supply are obviously least supplied, because long flow can not be maintained there without much loss from overflow. Holding the water in checks at the lower end—usually for two rows of trees—is quite a help toward even distribution.

THE FURROW SYSTEM.

The furrow system is the prevailing method of irrigating fruit lands in all parts of the Pacific coast. It is almost the only method indicated by correspondents in the newer regions of Idaho and eastern Washington. Possibly there, as in California, there are some soils which could be better handled with less water by the check system, but economy of water is of less account at the North at present, and distribution by furrows over quite porous soils is accomplished by using larger flows for a short time. It is, therefore, to be expected that as settlement progresses there may be, before long, recourse to the check system in those places to which it is suited. The furrow system has, however, a very marked theoretical advantage in the escape from saturating the surface soil, which has to dry out again before it can be cultivated, and is only with difficulty reduced to fine tilth after such puddling. Another advantage is in saving the water used in moistening soil which has to be dried by evaporation. Other theoretical advantages lie in the even distribution of the water with the least displacement of the soil and the introduction of the water to the subsoil, where deep-rooting plants should derive their chief sustenance. It is becoming quite clear that all these theoretical advantages have not been realized by the furrow system as generally practiced, and a number of modifications are now being introduced which promise their fuller realization. The scientific principles involved are also becoming better understood through investigation.[a] (Pl. IX, fig. 2.) The changes now taking place tend toward reducing the difference between what was formerly clearly differentiable as the "large-furrow" and the "small-furrow" methods, because the improvement lies chiefly in introducing the water more deeply in the soil, as will be shown later, and this is done by using fewer and deeper furrows. Still, the terms are useful. (Pl. VIII, fig. 2.)

IRRIGATING BY LARGE FURROWS.

Where one to four furrows are used, these are large furrows, while the small-furrow system uses from five to eight or more between two rows of trees. Large furrows are made with the double-moldboard plow, or with a single plow followed by the "crowder," or by plowing out dead furrows between the rows, etc. Their number depends upon the size of the trees and the fitness of the soil for lateral seepage. They are wide enough and deep enough to carry or hold a large stream of water, as shown by Pl. IX, fig. 3. This illustration also shows a method used chiefly for winter irrigation on land which is so nearly level that the water will flow slowly into the furrows and stand there until it disappears by percolation. It is also used where one or two summer irrigations are all that are required to carry the trees through.

[a] California Sta. Rpt. 1897–98, pp. 40–96.

FIG. 1.—CONTINUOUS CEMENT FLUME WITH WEIRS TO RAISE WATER TO OUTLET TUBES.

FIG. 2.—STARTING WITH THE "JUMP SCRAPER" TO CLOSE A ROW OF GAPS.

FIG. 1.—AQUEDUCT BENEATH A HIGHWAY FROM A MAIN DITCH TO FLUME SUPPLYING A VINEYARD.

FIG. 2.—"LARGE-FURROW" IRRIGATION OF VINEYARD FROM LATERAL, FOLLOWING A CONTOUR LINE.

FIG. 1.—NEWER SYSTEM OF FURROW IRRIGATION AT RIVERSIDE, CAL.

FIG. 2.—BOARD FLUME AND FURROW IRRIGATION AT FULLERTON, CAL.

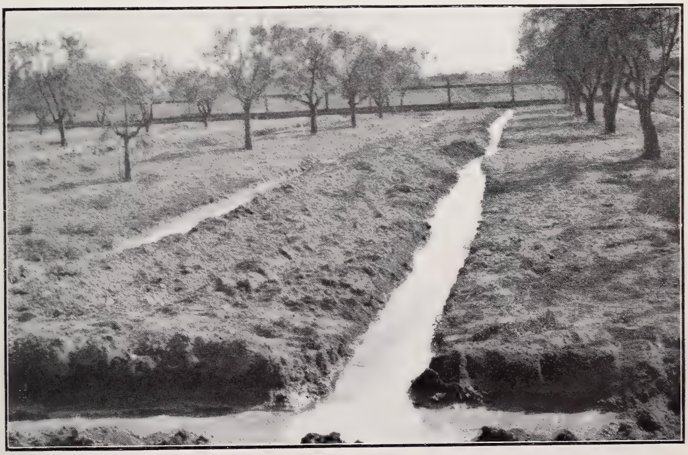


FIG. 3.—IRRIGATION OF OLIVE TREES BY LARGE FURROWS NEAR POMONA, CAL.

It is obviously adapted only to flat land or to land of uniform grade. Irrigation by a single furrow cut near to the row of trees is a widely prevalent method with young trees. When the trees are larger, or when intercultures are undertaken, the large furrows are multiplied. In this case the water is admitted to the furrows from a board flume. Large furrows are often used in a bearing orchard, the furrows being filled from a lateral ditch, this lateral being parallel to the main ditch. In this case the board dam is used to divert the lateral into one large furrow after another, and when the furrow is filled dirt is thrown in to prevent the reflow of the water into the lateral. The use of large furrows on sloping land is shown in Pl. IX, fig. 2, where the lateral follows a contour line and water is taken out on each side.

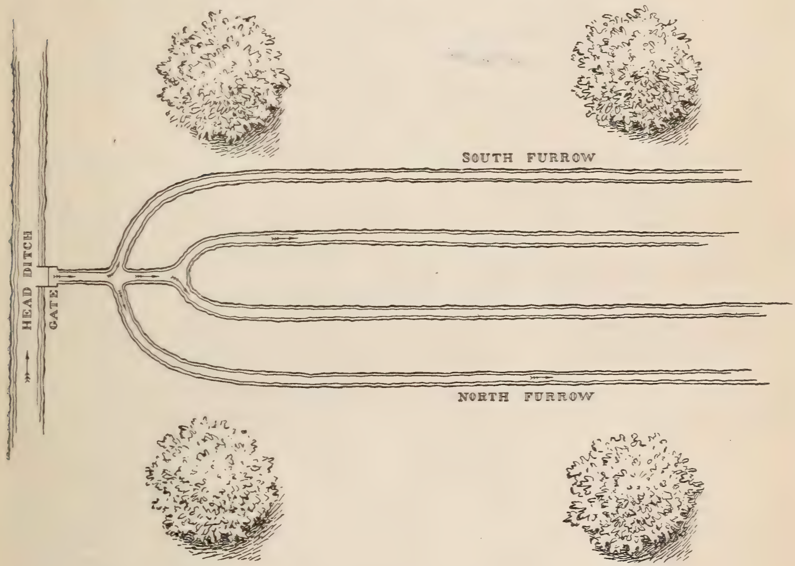


FIG. 5.— 'Large furrow" irrigation of orange trees at Palermo, Butte County, Cal.

The great variety in large furrow practice is suggested in the foregoing. A systematic manner of proceeding is that of Mr. A. Trost, of Palermo, Cal., as described by himself:

The soil is red, gravelly clay, the upper 12 inches without rocks; below this the gravel is more rocky. At the depth of 3 or 4 feet the red clay changes into a whitish one and water enters it very slowly. My orchard is 12 acres—1,120 feet long from north to south and 510 feet from east to west. The northeast corner is the highest. Here the water ditch enters, and I run my head ditch along the east side from north to south. There are 51 rows of trees in that direction, the north and south outside rows being olives. There are 23 orange trees in the row from east to west and 1 olive tree on the west end. All trees are 20 feet apart. I use 24 miner's inches per day for 5 days in the following manner: I use 4 furrows about 5 or 6 inches deep and about 3 feet apart between rows, leaving the furrows nearest the trees from 5 to 6 feet from the trunks (fig. 5). The 4 lower rows on the west side I cross furrow with 2 furrows between the trees. I divide the 24 inches into 51 equal streamlets by using one gate

for each 4 rows. First turn this amount in the furrow south nearest to tree. When the water has moved to the olive tree, I divide the water between the 4 furrows for the lower 6 trees and through the cross furrows. The next morning I divide the water at the tenth tree for the 4 furrows. On the third day I let only one-half the water go down in the furrow south of tree, the other in the one north nearest to tree. On the fourth day I turn part of it in the middle furrows near the head ditch, and by the fifth day I have my place equally wet from one end to the other, taking care that the top soil near the trunks of trees remains dry on the surface. I keep the soil around the trunks of the trees about 2 inches higher for a width of 3 feet. In this way I use all the water without running any off, and lose only the evaporation. The whole amount of water used is 120 inches, equal to 10 inches or 130,000 gallons per acre, or 4.5 acre-inches or 1,200 gallons per tree.

I irrigate about every four weeks, running the water five days and turning it on again three weeks after it is taken off. I have irrigated as early as the 1st of April and as late as the middle of October, depending on late rains in spring and early rains in fall; usually from five to six irrigations per year. After four or five days I cultivate 14 feet wide between the trees from 6 to 8 inches deep; for this I use a 7-foot cultivator and four horses. Near the trunk of the tree I work about 2 inches deep and a little farther away 4 inches deep, using the three-cornered orchard plow with a cultivator 4 feet wide and two horses.

IRRIGATING BY LARGE FURROWS WITHOUT SUM ER CULTIVATION.

An exception to the continuous cultivation of orchard ground which is prevalent in the irrigated regions of the Pacific coast is found in the foothills of the Sierra Nevada in California, where furrows are made at the beginning of each irrigating season and used continuously during that summer. The ensuing winter plowing and early spring cultivation are relied upon to keep the soil in good condition. Although this constitutes an exception and the practice is widely followed for what seems to the growers of the region to be good and sufficient reason, it does not militate against the truth of the continuous summer cultivation policy which elsewhere prevails, nor does it follow that this policy would not be better in some respects even in the region where it is abandoned. It is a district of very large water supply, and the arrangements of the water company are such that the grower must pay for a certain number of inches of water by the year and is entitled to this amount of continuous flow. He has to use it or neglect it as it flows, and can not get more at one time by not using it at another. For this reason he has not the motive for close observation which prevails under other conditions, and to escape the cost of summer cultivation and fresh furrowing out he has recourse to frequent flows in the old furrows. The following interesting account of the prevailing method was prepared by Mr. W. R. Fountain, of Newcastle, Cal.

Water is supplied almost exclusively by one company, which has met requirements up to date and seems fixed to supply in excess of demand. It is supplied by the miner's inch; price $45 per inch per season for a constant supply. The inch is measured under 6-inch pressure.

Beginning May 1, five months is called the irrigating season, but the purchaser can have the water twelve months per annum if he wants it. The water company collects monthly. The purchaser can not start the season with little and increase at pleasure, except upon payment for the full season on the basis of the largest amount used at any time.

With this constant supply we use it constantly, piping to high points and moving it from place to place. When no fruit is ripening it is attempted to water a block of trees in twenty-four hours. The water is not checked back, but is run in ditches, mostly in one, but occasionally in two, along each row of trees or vines. When a variety of fruit is ripening more water is given the trees, while after a variety is picked and before any other is nearly ripe the effort is made to water each tree every ten or twelve days. Level land and low spots stand a good chance, as a rule, to get too much water, and a larger stream is used per row to force the water through quickly. Then it is taken off in a shorter time than it would be where the trees are on a side-hill and have good drainage.

About 1 inch for each 8 acres is generally used. This is for deciduous fruits. The citrus fruits and berries require watering about once a week; if there is good drainage they would prosper if watered every three days. In such ground I have not heard of their getting either too much water or too much fertilizer. The general practice is to plow, cross plow, and then after each rain cultivate, with no cultivation whatever after beginning the use of water. I think an occasional cultivation after watering would help.

There is a tendency for the ditches to become packed after water has been flowing through them for some time, in which case but little water soaks into the ground. When this occurs, I dig a pot-hole in the ditch to allow the water to soak in, or else loosen the ground about the trees with a spade and carry the ditch through this loosened ground. I block out my ditches so that I can get my stream through to the last tree in about sixteen hours. Where the water has not reached the end of some of the ditches, I turn the water into it from a stream that is flush, and by keeping a man with a hoe constantly with the water, I manage to get it over the field at about 4 p. m. I wet about 350 trees in a block on hillsides; on a flat I wet less, using more water in each stream, and changing it about every twelve hours nstead of every twenty-four hours. My trees grow about 130 to an acre.

SYSTEMATIC DISTRIBUTION OF WATER ON HILLSIDES.

The common method of carrying water in pipes to the various high points of several slopes or "irrigation faces" from which it can be admitted to large furrows crossing or descending those faces is open to some difficulties and disarrangements. P. W. Butler, of Penryn, Cal., has had in successful operation for several years a system of zigzag ditches for carrying and distributing and for catching outflow and redistributing on a lower face. This is also a system which makes ditches and furrows but once a year and dispenses with summer cultivation. Mr. Butler's account, as illustrated by the accompanying diagrams, is as follows:

The amount of water generally used in this section for the irrigation of deciduous fruit trees is 1 inch to 5 acres of orchard (miner's inch under 6-inch pressure), and is applied to each row of trees by one stream of water of sufficient quantity to just reach the end of the row. Much of the water is thus wasted because of inability to properly adjust its distribution. It is usually run twenty-four hours, then changed to

other parts of the orchard until the whole is covered, which takes about three weeks' time, when the process is repeated, continuing throughout the summer, or from May 1 until October 1. There is no cultivation in the meantime, and at each irrigation the water is run in the same ditches. This system is followed in nearly all the orchards of Penryn and vicinity, some on quite steep hillsides, which suffer when the water is thus applied. I have never liked this method, and for many years have used a different system in irrigating all orchards over which I have had control. In my home orchard I have a reservoir on the highest land, from which water can be conveyed as desired to every part. My ditches are run on a grade with a fall from 2 to 3 inches to the rod and from 5 to 8 feet apart. At each irrigation the water is run about thirty-six hours before changing. The round of the orchard is made in ten to fourteen days. None of my small ditches exceeds 400 feet in length. When I begin to irrigate a section I turn on from the reservoir water sufficient to cover that section in a few hours, then lessen it until it just reaches the end of each row, but see that it reaches the end of each row even if a little surplus passes over. This surplus I take up in a main ditch, to be again used on lower ground. This is continued until the

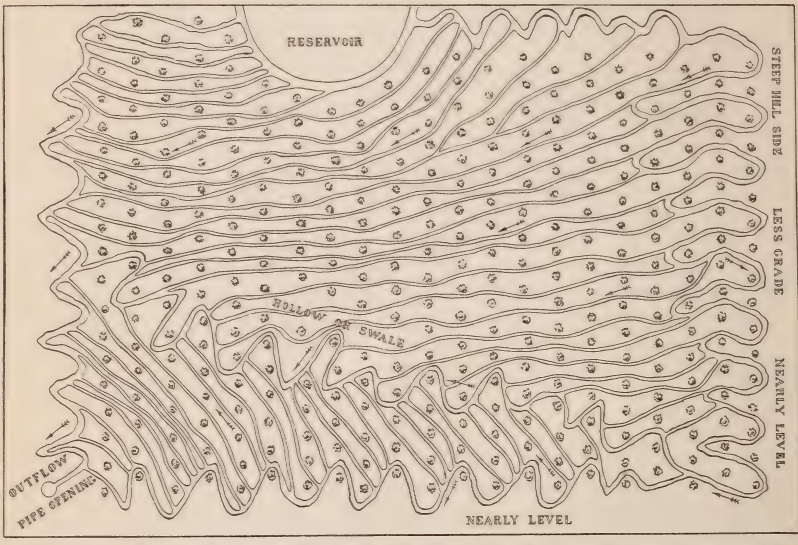


Fig. 6.—"Large furrow" system on hillsides, with zigzag ditches for distribution, catchment, and redistribution.

lowest part of the orchard is reached, and very little water is ever wasted. By running on a grade that is so nearly level the water is applied uniformly, even on the driest parts of the hill slopes. I run the main distributing ditches in a zigzag manner, taking water from these ditches to cover the lower sections. I formerly used pipes to lead the water down the steepest grades, but this system I have abandoned and now use open zigzag ditches for mains (fig. 6). From the main zigzag ditches I do not take the water at the turning point, as there is more liability of breakage than if taken when running straight, or at whatever point is necessary to keep the distributing ditches on an average of 8 feet apart. The length of the zigzag ditches varies according to the slope of the hillside. When steep, the ditch, before turning, must be of greater length than where the ground is more level. (See diagram.) I use no gates, but bush the openings with coarse swale hay. I also bush the turning points of ditches, as they are in permanent use throughout the season, and after the first

few days' use require but little care to keep them in order. These ditches are torn up during the season of cultivation and have to be renewed every year.

I use a level set on a frame 8.25 feet long and about 2.5 feet high (one leg longer than the other) to make any grade desired (fig. 7). This I drag its length on the ground after getting the level, and can mark the line of ditch nearly half as fast as a man can walk.

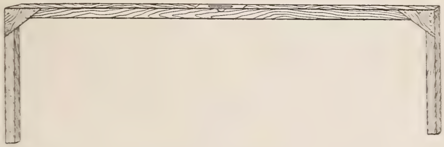


FIG. 7.—Handy level for locating large furrows in hillside irrigation.

During the last ten years I have used many thousand feet of pipe in irrigating, but have found it too expensive to be practicable, and it frequently gets clogged, causing much trouble. The zigzag method of taking the water down hills on the dry ridges, distributing to right and left, picking it up again in zigzag ditches at the end of the rows or system, to be used again on lower ground, brings into use the largest quantity where it is most needed and utilizes it all without waste.

IRRIGATING BY SMALL FURROWS.

It has already been suggested that recently the small furrow method of irrigation is undergoing certain modifications. The occasion for the change is that in certain of the heavier soils, particularly, the use of water in many shallow furrows followed by cultivation results in the formation of a compact layer, and this prevents the percolation of the water into the subsoil. This discovery led many Southern growers to resort to fewer and deeper furrows and to new devices to enable the tree to get the benefit of the water. There has been wide use of the subsoil plow, with a wedge-shaped foot attached to a slim standard rising to the ordinary beam. The standard opposes its thin edge to the soil so as to cleave it with the least difficulty, and the foot, passing through or beneath the hardpan, lifts and breaks it. The result of the subsoiling is to open a way for the water to sink and spread below the hardpan. It is usual to run this plow once through the center of the interspace between the rows of trees, sometimes at right angles to the irrigation furrows. When this is done the water is admitted to the furrows as usual, but instead of flowing along smoothly it drops into the track of the subsoiler and runs there a long time before rising again to continue its course down the furrow. It is the experience of some growers that the water has taken five or six days to reach the lower end of the furrows, a distance which would have been covered in twenty-four hours if the subsoiler had not intervened. This has been shown to result in much water for the subsoil and a notable invigoration of trees which had been famishing, although shallow-furrow irrigation had proceeded regularly.

Recent changes in the furrow method at Riverside, Cal., are described by Mr. J. H. Reed as follows:

The handling of the water in the orchard has materially changed in recent years. Instead of flooding up, basining, or using shallow furrows, deep furrows, from 3 to 5 feet apart, are most generally used. In heavy adobe soils more furrows are used than in the more porous granite soils. The most usual length of furrows is 40 rods. Every pecaution is taken to have the surface wetted as little as possible.

The amount of water run at a time is materially lessened. Formerly the common practice was to run 3 inches per acre for twenty-four hours each thirty days. Now, 2 inches continuous run for seventy-two hours is found to serve a much better purpose, except on loose soils. The general practice in the valley is to irrigate once each thirty days. A few of the most careful orchardists had found that by intelligent and thorough manipulation of the soil they obtained as favorable results from the application of water every sixty days or more, using the same amount as they formerly did at intervals of half that time. The writer has watched with much interest an eight-year old orchard that during the three years preceding the present received in all but ten irrigations, the usual amount of water being used only at each four irrigations the first year and three irrigations each the second and third years, with results comparing favorably with those on trees of the same age on the same soil in neighboring orchards that received the ordinary thirty-day irrigations. While there are yet few orchardists who have the skill and patience required to secure such results, they show the possibilities of improved cultivation in conserving moisture. So long as water is abundant and not expensive, more frequent irrigations will probably be generally practiced; but the advantage of running the water slowly for a longer time, in furrows as deep as possible, covering the saturated bottoms as soon as practicable and keeping the surface perfectly pulverized and in loose condition, is being generally recognized.

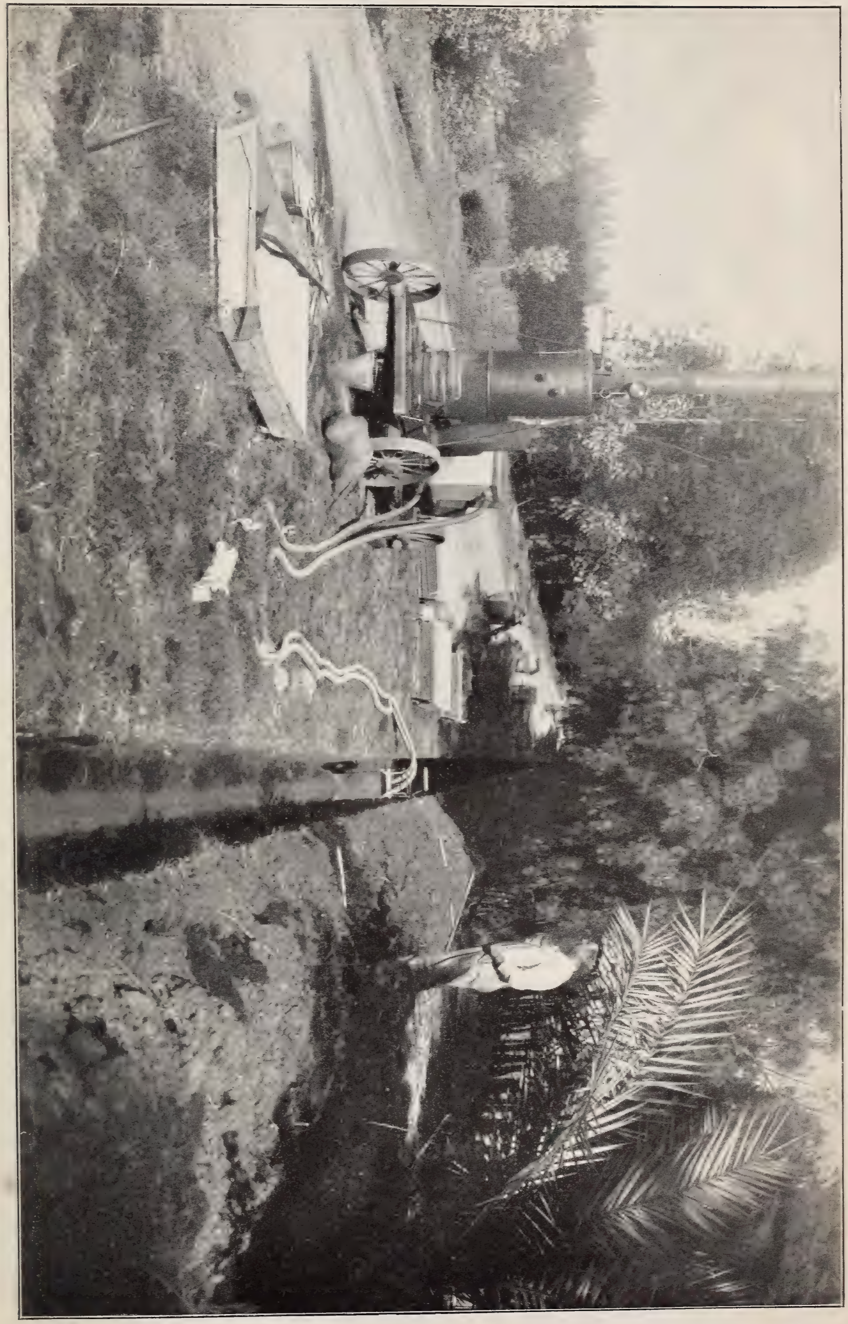
Pl. IX, fig. 2, shows the water flowing in the furrows to which Mr. Reed alludes. A young orchard is selected to better show the furrows. The usual practice is now to have 6 deep furrows in 20-foot spaces. The number varies according to the character of the soil, but is in any case less than in the small, shallow furrow system which formerly prevailed.

The recourse to deeper furrows and to the subsoil plowing has been made in several citrus fruit districts of southern California. Its success depends upon conditions. There are cases in which too deep use of the subsoiler has admitted the water at a point too low for best results to the tree which grows on a leachy subsoil, and the cutting of roots by the subsoiler has in some cases brought shallow-rooting trees into temporary distress. The general conclusion, however, is that deeper introduction of water favors deeper rooting and is very economical of water by preventing the loss by evaporation from the surface, which, theoretically, is dry, but which actually, with shallow furrows over an irrigation hardpan becomes too often saturated over nearly the whole space between the trees.

CEMENT PIPES AND FLUMES FOR THE FURROW SYSTEM.

A general account of the small-furrow system has already been given,[a] and a more specific account of some of its details will be added.

[a] U. S. Dept. Agr., Farmers' Bul. 116, pp. 38–41.



MACHINE FOR MAKING CONTINUOUS CEMENT PIPE AND FLUME AT RIVERSIDE, CAL.

The use of cement in the construction of flumes has largely increased because, by means of locally devised machinery, continuous cement flume has been cheapened so that its first cost is less than that of lumber flume where suitably durable lumber is high. Similar machinery is used for the construction of continuous cement pipe, which is replacing open laterals in carrying water from main ditches to the land of individual irrigators. This pipe is made by a machine constructed by two Riverside men who are both machinists and practical orchardists. Pl. X shows the outfit in operation. Sand and barrels of cement are distributed along the line ahead of the machine, as shown in the background of the picture. The mixing is done in the flat boxes, each being carried forward when emptied. One of the lines of large rubber hose conveys steam to the head of the cylinder of the machine and the other returns the spent steam. The mixed cement and sand is carried to the feeding box (shown in vertical position in the trench), from which it is dropped into the steel pipe form below. Steam pressure is then brought to bear upon it and then cut off by the lever; loose earth is thrown around the steel forming-cylinder as it moves forward and is firmed by the operator's feet ready to sustain the walls of the new pipe as the cylinder is withdrawn from it. More loose earth is thrown over the new pipe, which is allowed to harden before the trench is filled.

Continuous cement flume is made in a similar manner, the machine working on the surface and the required pressure being given by a strong lever instead of by steam power. Instead of a cylindrical form, one to properly shape the flume is used. After this form is moved and before the cement hardens, grooves are made at intervals in the side walls to insert board dams to raise the water so that it will flow out of the zinc tubes with gates, which are also put in place while the cement is plastic. Not only is such flume sometimes cheaper than board flumes, as stated above, but annoyance of leaking and cost of extensive repairs are done away with. (Pl. VII, fig. 1.)

THE BOARD FLUME AND THE FURROW SYSTEM.

Although in the older regions the cement flume is advancing in popularity, important service will always be rendered by the home-made board flume where suitable lumber is cheap. A detailed account of its construction and operation will be widely useful. The following is contributed by Mr. A. S. Bradford, of Orange County, Cal., whose arrangements are shown in Pl. IX, fig. 1:

I consider the board flume best because it is in many places cheapest and because it will last fifteen or twenty years in California if made of good soft redwood. The common redwood lumber is generally so, but the so-called flume lumber is hard, generally, and will warp the flume out of shape. Even in the common redwood lumber hard pieces will be found, and these should be avoided. My first flume has been in use nine years and is apparently as good as ever.

The first thing to be considered is getting a flume put in properly, as this alone will cause much trouble if not done right. A flume should run nearly on a level. It should be placed about two-thirds in the ground at the commencement, and, as

soon as it comes out of the ground to about two-thirds of its height, there should be a drop made of 1, 2, or 3 inches, if necessary, and then carried along as before, so as to keep the entire length of flume practically on a level.

Sixteen-foot lumber is better than longer, as it is lighter to handle. I prefer 8-inch sides with 18-inch bottom, or, in some cases, 10-inch sides with 16-inch bottom. The first section, however, should be about 2 feet wide, narrowed to the size of the flume, so as to control the stream. Collars should be put around the flume every 8 feet of distance; that is, one in the center and one to cover the joints at each end. These collars should be 2 by 3 inch stuff on the bottom and sides and 1 by 3 inches on top. This makes a strong, durable flume. The length of the flume should be divided, so that the stream will decrease as it goes along. The width should be decreased also, say from 16 inches to 14, 12, 10, and 8 inches, the sides being the same throughout or reduced so as to have 10-inch sides on the 16-inch bottom and 8-inch sides on the rest, nailed to the side of the bottom, making 7 inches depth inside. Two-inch holes should be about 30 inches apart and 2-inch gates placed on the inside instead of outside, as they will collect less trash, the hole through the wood, if uncovered, making a lodgment for leaves, etc. In the narrow and flat flume it is much easier to fix the gates.

From 8 to 9 furrows for trees set 24 feet apart are sufficient. The streams should be run from one-eighth to one-half the capacity of the holes in the flume, according to the soil and fall of ground. I commence the stream small and increase it if necessary later on. The streams should be kept as near together as possible, and when the end is reached the gate should be nearly closed down, so as to allow the stream to just trickle to the end. In this manner the soil will become thoroughly wet from one end to the other. The streams should be run very slowly on most of our soils. A great many failures have been made on hard soils by running the stream too large and then reducing it. This seems to "slick" or cement the soil so that it will not take the water, and the consequence is a poor and unsatisfactory irrigation. On the other hand, if the streams are started small and allowed to soak the ground as they go along, it is simply astonishing how much water can be put in the ground. On sandy soils the streams should be larger. A little practice would give anyone the desired information.

About three rows of trees at the lower end should be blocked up, provided one has no place where the overflow water could be used. This last provision is the better, however, as there would be only about 10 inches of water run over the last three or four hours, and a thorough job would be done from one end to the other.

In making furrows I have an extension made for my cultivator to bolt on each side and use four plows. With this extension I can wet the whole ground thoroughly. The furrows will extend under the limbs of the trees, and by making a slight curve around each tree the ground will become wet in the rows as well as between.

As compared with the check system, the furrow method, properly handled, makes the soil light and loose, while the check system is apt to pack the soil, rendering it lifeless and leaving it so that it will not retain moisture long. Besides, the cost of ridging and extra labor in handling water in checks for one season will nearly pay for the flume by which one man can do the irrigating. Two horses will furrow out 10 acres in half a day, and a little hand labor at the flume will connect the furrows. In the check system generally a disk is run first where the ridges are to be made, and then the ridger is run with 4 horses; then the jump scraper is run to stop up one side of the blocks; then ditches must be made; then from 2 to 3 men are required to handle the water by shutting up the checks when filled. Afterwards the ridges must be plowed down before the ground can be harrowed and got in condition to cultivate. At a glance one can see that it costs fully three times as much to irrigate by the check system as by the furrow system, and with the latter the soil acts more as it does after a rain.

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